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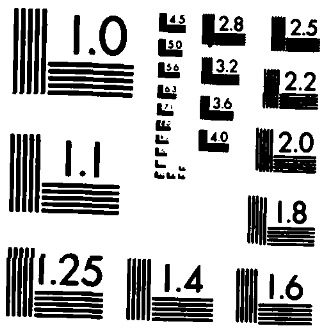
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NRL Memorandum Report 5360

Synoptic Observations of the Radio Noise Background in the Frequency Range 150-180 kHz to Provide Design Data for the Low Frequency Communications Designer

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Observations were made of the radio noise background in the frequency range 150-180 kHz to provide reference data for the design of the Ground Wave Emergency Network (GWEN) system. These observations were undertaken at Nanjemoy, Maryland, during early summer 1983, and included forty-one days of data recording. The noise environment was found to be dominated by impulsive thunderstorm noise. Preliminary data analysis is presented; the recorded data is available on magnetic tape for authorized users to use for system design purposes.

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CONTENTS

EXECUTIVE SUMMARY

The Air Force has recently identified a need for a low-frequency emergency communications system using ground wave propagation in order to provide reliable communications during times of electromagnetic disturbance. To select appropriate modulation and error correction techniques to meet the system reliability requirements it is important to know the detailed characteristics of the noise and interference background. The GWEN system has been tentatively assigned to operate in the frequency band from 150 kHz to 180 kHz. In this frequency band, there is reliable ground-wave propagation; at night, skywave propagation is usually also seen. The noise environment during both daytime and nighttime conditions is thought to be dominated by impulsive atmospheric noise from lightning strikes. This noise is known to have definitely non-gaussian statistics; in particular, the number of high-amplitude events is significantly greater than predicted from a Rayleigh amplitude distribution. Although approximate statistics for this type of noise are known (4,5,9,29), extensive observations have not been performed for the frequency range in question. Accordingly, a series of observations was initiated at NRL's Maryland Point Observatory in southern Maryland. Since the atmospheric noise is non-stochastic and is a function of time-of-day, weather patterns and season, a synoptic monitoring program is needed for full parameterization. The monitoring site and period of observation, however, included late spring and early summer weather at a site with reasonably high thunderstorm activity, so should represent an adequate sample for worst-case conditions. Several thunderstorm fronts passed over our monitoring site during the course of the project. Our experiment recorded 41 days of data quasi-continuously between May 19 to July 9, 1983, using several different equipment configurations, and provides a satisfactory preliminary noise data base upon which to base GWEN design parameters.

The noise waveforms from the receiver were Nyquist sampled and digitally recorded for later analysis. The background noise level was found, in general, to consist primarily of impulsive noise with non-gaussian statistics. The mean noise level was found to be much higher between sunset and sunrise than during the day. A typical nighttime mean noise level was 1×10^{-15} W/m^2/Hz, while a typical daytime level was at least 14 db quieter. However, the daytime level was at times significantly higher, especially during the presence of a local thunderstorm front. The highest power impulses often occurred during the afternoon period, between 15:00 and 21:00 EDT. During local thunderstorm activity, impulses with peak power of 1×10^{-14} W/m^2/Hz were observed frequently, while the most energetic pulse detected during our monitoring period has a peak power of 6.8×10^{-14} W/m^2/Hz. The impulsive noise is well correlated with active local thunderstorm systems. The duration of a typical lightning noise event was of the order of 0.5 seconds.

In addition to these preliminary conclusions, an important part of this work was the provision of an archival data base of our recorded data for detailed analysis and comparison with noise and modulation models by MITRE Corp and other DoD authorized users.

SYNOPTIC OBSERVATIONS OF THE RADIO NOISE BACKGROUND IN THE FREQUENCY RANGE 150-180 kHz TO PROVIDE DESIGN DATA FOR THE LOW FREQUENCY COMMUNICATIONS DESIGNER

EXPECTED RADIO NOISE BACKGROUND IN THE FREQUENCY RANGE OF 150 to 180 kHz

The properties of the radio frequency range below 30 kHz (VLF) have been extensively studied (23), but those of the LF range (30-300 kHz) have been much less so, although a general data base has been compiled (29). In general, LF radio propagation can be expected to share many of the properties of the VLF spectrum modified by differences in propagation in the two frequency domains. Our investigations generally supported this conclusion. An estimate of the magnitude of the average noise can be obtained from the data in C.C.I.R. Report 322 (29). For the location of the Maryland Point Observatory the curves in this report give expected noise levels at 163 kHz corresponding to noise factor (F_a) values between 95 dB for the daytime low to a high nighttime peak of 121 dB. In the units used in this report, this corresponds to 6.6×10^{-17}W/m^2/Hz and 2.6×10^{-14}W/m^2/Hz respectively.

In parameterizing the LF noise background, there are two important considerations; the source of the natural noise background, and the propagation conditions from the noise source to the receiver. A third important consideration in this frequency range is man-made interference, but no systematic study was made of this for this report. Systematic models have been made of the propagation characteristics and noise background for VLF(11,13,15), but cannot be extended to LF without modification.

Atmospheric radio noise in the VLF band is primarily a result of lightning discharges occurring in the earth's atmosphere (5,6,7,17,19,21). For electric-field antennas located in dry, windy environments precipitation static can become an important noise contributor. On occasions solar disturbances can cause a noise background increase known as Sudden Enhancement of Atmospherics. Nyquist noise associated with the receiver, or with the terrestrial or extraterrestrial background, is generally negligible, unlike the situation at microwave frequencies. Propagation upward or downward through the ionosphere has a high enough attenuation to make extraterrestrial noise a negligible factor in the 150-180 kHz band, although signals can be propagated through the earth-space interface(2).

The large impulsive type currents associated with lightning phenomena cause electromagnetic radiation which is propagated to the receiver; this radiation has been investigated by Watson Watt and others (18,20,21,22,25). The initiating predischarge or 'leader' stroke develops over a period of a few milliseconds. It consists of a series of discrete sub-leaders occurring at a rate of one every .025-.1 millisecond. The total time required for the leader to reach the ground is .5-1 millisecond. Following the pre-discharge leader, a single ground-to-cloud discharge stroke occurs lasting .1 milliseconds with a peak intensity of 20,000 amperes. Frequently, 'long' discharges can occur consisting of several strokes each lasting .1 milliseconds, separated by an average period of 40 milliseconds; thus a single stroke can extend over a time interval of several hundred milliseconds. The total power in a single discharge lasting 100 milliseconds is 500-1000 megawatts, much of which goes into ionizing the atmosphere and generating acoustic noise. It has been estimated that as much as 1 megawatt remains for generating the RF field

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(6,23). The radio frequency noise that is generated is impulsive in character (8), with a duration that corresponds to the physical duration of the lightning stroke. The peak frequency of the radio frequency noise is in the broad range of 5-50 kHz; estimated signal strengths, normalized to a distance of 1 km., can be as high as $2 \times 10^{-7} W/m^2/Hz$ at a carrier frequency of 5 kHz. The appropriate estimate for the vicinity of 100 kHz is $2 \times 10^{-12} W/m^2/Hz$ at a distance of 1 km, and is estimated to gradually decrease with increasing frequency at a rate of 3 dB/octave. This is still a highly significant source of noise.

The occurrence of lightning discharges varies from place to place on the earth(10). Lightning discharges are very rare in Arctic and Antarctic regions and can be as low as 1 discharge per second in temperate regions or as high as 100 per second in the tropics. At any one time there are approximately 2000 thunderstorms in progress worldwide (2). In the temperate regions especially, the thunderstorm incidence is a strong function of the season of the year.

Ground wave propagation and sky wave propagation (ionospheric bounce) are the principal modes of propagation that take place at LF frequencies. The ground wave, which is the basis of the GWEN system, is a very effective propagation mode at 165 kHz due to refraction at the earth's surface; for example, at a distance of 1000 km the ground wave should be attenuated by only about 20 dB more than the $1/r^2$ geometrical attenuation. Ionospheric propagation is considerably more variable; however, a clear day-night effect is usually present, with the sky-wave propagation being much more efficient from sunset to sunrise than during the daytime. This is due to a difference in ionospheric reflection coefficient that is somewhat complex to predict, but is due basically to the reflection occurring at lower altitudes during the day where the higher density causes a decrease in effective ionospheric conductivity. The net power delivered to the receiver by skywave propagation from distant thunderstorms can be appreciable if there is a large thunderstorm front being propagated. In addition, a focusing effect is possible giving path losses significantly less than $1/r^2$. Waveguide-mode propagation, although important at VLF(1), is not expected to be a significant effect in the 150-180 kHz range.

A typical ground station is thus expected to observe two noise components; local noise from nearby thunderstorms within 500-1000 miles, propagated via the ground wave, and a component due to distant thunderstorms propagated via sky wave. Since the local component consists of contributions from appreciably fewer lightning strokes, it might be expected that it would be of significantly more impulsive character than the sky-wave component which might consist of many pulses overlapping in time to create a quasi-continuous background. Improved sky-wave propagation will cause the background level to increase as progressively more distant thunderstorms are able to contribute to the received RF field. The impulsive component, on the other hand, should be much more sensitive to local weather where the RF field is dominated by individual lightning strokes.

The robustness of a receiver system in the presence of background noise depends on both the characteristics of the noise background and on the modulation characteristics of the desired signal; our present work did not investigate this subject in depth. Work on receiver noise sensitivity has been performed by Watt et al and others (14,24); there is a fairly extensive literature on characteristics of non-gaussian noise expected at these frequencies (16,26,27,28). The present investigation focused on obtaining a valid statistical data base for further analysis, and on determining basic noise parameters in the frequency range considered.

EXPERIMENTAL PROCEDURE

To study atmospheric noise realistically requires a high dynamic-range receiver that can produce wide-bandwidth samples of natural-background noise over a selected period of observation. In addition, the need for rapid results required the use of equipment available "off-the-shelf". From available equipment, it was possible to make a working system which consisted of a magnetic pickup loop, connected through preamplifiers to commercial (Hewlett-Packard) wave analyzers, which were set to act as a single-sideband superheterodyne receiver with adjustable bandwidth and center frequency. The bandwidth was normally set to 3.1 kHz, the largest value available. Undetected i.f. noise instead of envelope data was recorded to maintain full flexibility in later coherent signal analysis. Envelope and other information was created by computer post-processing. During the latter portion of the experiment, a computer-controlled attenuator was used to set the system gain in steps of approximately 20 dB to extend the system dynamic range. The atmospheric noise level during the quietest daytime conditions was about 5 dB higher than the output of the first preamplifier at the loop site. The video output of the wave analyzer was digitally sampled at a rapid rate and recorded on a computer tape. The recording system was controlled by a Hewlett-Packard 2116C computer system that had previously been used in several similar real-time equipment control projects. The block diagrams of the equipment are shown in Figs. 1-4, and the data control block diagram is shown in Fig. 5. Two channels of data were recorded with 12-bit precision; various configurations were used throughout the course of the experiment as detailed in Figs. 1-4 to record different signal levels to enhance the dynamic range. The data log is transcribed in Tables I-III. A dynamic range of 120 dB was desirable; the 12-bit analog-to-digital converters used had an effective dynamic range without changing settings of about 60 dB, as did each wave analyzer used. The second channel was usually set at about 40 dB lower gain to give a total range of 100 dB. The actual data-taking format was controlled in a versatile manner by a real-time HP2116 computer programmed in Forth. A block diagram of the data-taking program is shown in Fig. 5; listings of the code are in Appendix B, but it should be noted that a full explanation of the code is not attached.

The data-taking routine operated approximately as follows; at start of execution of the Forth word, values for the various parameters detailed in the identification section were typed in from the system terminal. These included frequency, bandwidth, location, sample interval, etc. The start time was obtained from the U.S. Naval Observatory telephone time service and was used to start the internal time-keeping of the computer, which consisted of a crystal-controlled 0.1 second interrupt generator, with an epoch accuracy of about $\pm$0.2 seconds. When time for a sample to be taken was at hand, control was transferred to a sampling routine. This routine recorded data at a rate which was controlled by interrupts generated by an external synthesizer, which was set at approximately the Nyquist rate for the bandwidth used. For the 6 kHz rate used for most of the sampling, the sample interval was 167 microseconds. The sample from the second channel was recorded close to simultaneously with that from the first channel; there was, however, a 25 microsecond delay due to hardware constraints in the multiplexer. A tape record consisted of 5000 samples from each channel, covering a total interval of 0.833 seconds, together with identification information. Some of the early

data was recorded with a synthesizer frequency of 10 kHz, resulting in a sample interval of 100 microseconds and a record length of 0.5 seconds. Later data was recorded in groups of ten records to ensure good sampling of the medium-term statistics of the lightning-associated noise. There is a data gap of 0.022 seconds $\pm$0.001 seconds between tape records within a group to allow for program overhead in recycling for the next record. A major limitation in the amount of data recorded was the volume and expense of the magnetic tapes. A limit was somewhat arbitrarily set of recording one magnetic tape per day; at our 800 bpi recording density this meant that we could record about 1000 seconds per day total, or about 1% of the time.

For the majority of the data, both channels were recorded at the same nominal center frequency, with all parameters the same except for the gain setting. The question then arises to what extent the two channels can be combined to equivalence a single channel with larger dynamic range. The answer for our experiment is that for purposes of determining the noise envelope, data from both channels can be combined freely. However, both channels cannot be combined in a fully coherent fashion primarily because the bandpass characteristics and center frequencies were not identical.

Calibration of the URM-6 loop gain was performed by the method described in Jean et al (12) to establish the relationship between the signal input to the test port of the loop and field strength. An overall system calibration was performed by introducing a known signal level into the test port of the loop and recording the output for the data-taking system. Because the antenna and the preamplifier were operated as an integral unit, no sensitivity figure was determined for the antenna alone; but the overall system calibration was determined to be: 1 unit of power = $2.78\text{X}10^{-21}\text{W/m}^2/\text{Hz}$, where one unit of power is defined as: one count^2 on channel one, with the digital attenuator set at a value of 1 and all system gains set as indicated in Fig. 3.

It should be noted that all signal strengths in this report are given in units of power spectral density, watts per square meter per unit bandwidth. This type of measure is appropriate for impulse-type, or wideband, noise. The power units are easily convertible to field strength in microvolts per meter by use of the formula:

$$P = \frac{E^2}{R}$$

where P = Power density
E = field strength
R = the impedance of free space, 376.3 ohms

The overall frequency response of the system was calibrated by injecting a signal into the antenna and measuring the level at the input to the analog-to-digital converter. The result, which is the overall system response, is shown in Figure 7. Figure 7 is for the HP3590A wave analyzer, which was normally considered our primary channel. At a nominal observing frequency of 165 kHz, a frequency of 163.2 kHz is converted to zero frequency, and the mean observed frequency is about 164.8 kHz. A response curve for the wave analyzer alone is shown in Figure 6.

OBSERVATIONS

Because of the rapid time scale of the project, the final equipment configuration was decided upon while the experiment was in progress. Four equipment configurations were used for appreciable periods of time. These are labeled Systems A, B, C and D and are set forth in block diagram form in Figs. 1-4. While the latter configurations were in general an improvement over the earlier ones, the earlier data was judged worth retaining. The data from the period before 13 June (Systems A and B) is most useful for purposes of determining the average noise statistics, that during the period 13-27 June (System C) for determining peak statistics, while that taken on 28 June and after (System D) should be useful for both purposes.

The experiment was initially set up in Building 209 at the Naval Research Laboratory, Washington, D.C. However, it was quickly determined that various sources of man-made local interference, primarily from computers, were dominating the output, so the base of operations was transferred to our radio astronomy field station at Nanjemoy, Maryland. This station is located on the Potomac River in a primarily rural area about 40 miles south of Washington. Its approximate geographic latitude is 38 22.4' North, and its longitude is 77 13.9' West. Local interference was not a significant problem at this site. There were, as expected, several interfering carriers present in the general frequency band; the primary observation frequency of 165 kHz was chosen to minimize this problem after monitoring of the frequency band. Observations, undertaken quasi-continuously during the period 13 May - 8 July 1983, were recorded on a series of magnetic tapes. The background was monitored at one-to-ten minute intervals during almost all of this interval; occasional exceptions were due to configuration changes, equipment failure or, most often, power failure at the site due to thunderstorm activity. During this time, there was a fairly typical assortment of Washington-area early-summer weather, including several periods of local thunderstorm activity as well as fair-weather periods. The weather environment was monitored in a quantitative manner by the installation of a rain gauge at the site, as well as by daily videotape recording of the national weather pattern, including the digital radar map that is an excellent indicator of precipitation activity.

In analyzing data from a specific period from this project, it is vital that the user refer to the data-related tables at the back of this report, the synoptic atlas of LF noise levels. There are three data-related tables. Table I, entitled List of Significant Changes and Settings in Data-taking Procedure, lists all the generic changes in data-taking procedure and is important to consult to understand the data recorded. Table II, entitled List of Unique Characteristics of Individual Tapes, records non-standard features of particular tapes. Table III, the Data Tape Log, includes start time, interval, and all other data parameters that were changed on a daily basis, as well as a summary of the weather information.

A significant purpose of this experiment was to create an archival data base of LF noise data that could be used for signal processing simulations during the GWEN design effort. NRL is therefore willing to supply copies of this tape data base at nominal duplication cost to authorized groups. For further information contact:

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THEORY OF ANALYSIS OF UNDETECTED WIDEBAND SAMPLES OF LF NOISE

To maintain flexibility in later analysis, date was recorded as a wideband undetected data stream. Since data of this type is not in wide use in the field of LF signal analysis, it is appropriate to discuss some basic precepts for analysis. A 6 kHz sampling rate is assumed.

The detected voltage at 165 kHz in a 3100 Hz bandpass is down-converted to a base band at 1550 Hz center frequency and then Nyquist sampled at 6000 Hz for a period of 833 milliseconds. The instantaneous voltage can be described as

$$v(t) = V(t) \sin (2\pi f t + \phi(t))$$

where $V(t)$ is the slowly varying voltage of the noise envelope, f is the frequency of the center of the observing band (1550 Hz) and ϕ represents the phase of the received signal. The average received noise power, P, during a sample period of T seconds is

$$P = \langle V(t)^2 \sin^2 (2\pi f t + \phi(t)) \rangle$$

Since the envelope power is a slowly varying function of time and is physically uncorrelated with the band center frequency f,

$$P = \langle V(t)^2 \rangle . \langle \sin^2 (2\pi f t + \phi(t)) \rangle$$

which simplifies to

$$P = \frac{1}{2} \langle V(t)^2 \rangle$$

where

$$\langle V(t)^2 \rangle = \frac{1}{T} \int_0^T V(t)^2 \, dt$$

We see that the mean observed power P is equivalent to the average envelope power $V(t)^2$.

In addition to the average power in each 833 millisecond sample it is also possible to calculate the voltage deviation V_d which is related to the impulsiveness of the incoming signal. It is defined in terms of the instantaneous envelope voltage as follows,

$$V_d = 20 \text{ Log } \frac{\langle V'(t)^2 \rangle^{1/2}}{\langle | V'(t) | \rangle}$$

where

$$\langle V'(t)^2 \rangle = \frac{1}{T} \int_0^T v(t)^2 \, dt$$

$$\langle V'(t) \rangle = \frac{1}{T} \int_0^T |v(t)| \, dt$$

The quantity $\langle V'(t)^2 \rangle$ can be easily derived from our expression for the detected mean power P

$$P = \frac{1}{2} \langle V(t)^2 \rangle = \langle V'(t)^2 \rangle$$

The quantity $\langle |V'(t)| \rangle$ is obtained from our measured quantity v(t) by the relationship

$$\begin{aligned} \langle |V'(t)| \rangle &= \langle |V(t) \sin (2\pi f t + \Phi (t))| \rangle \\ &= \langle |V(t)| \rangle \quad \langle |\sin(2\pi f t + \Phi (t))| \rangle \\ &= 2/\pi * \langle |V(t)| \rangle \end{aligned}$$

AMPLITUDE AND TIME PROBABILITY DISTRIBUTION

The Amplitude Probability Distribution (APD) represents the percentage of time that the noise power exceeds a given threshold level. If the instantaneous noise power is defined as $P(t) = V(t)^2$, we can construct the function p(t) such that

$$
\begin{aligned}
p(t) &= 1 \qquad \text{for } P(t) > P_o \\
&= 0 \qquad \text{for } P(t) < P_o
\end{aligned}
$$

where P_o represents the threshold level. We then integrate this function over the sample interval to determine the percentage of time that the signal exceeds the value P

$$
APD(P_o) = 100\% \cdot \frac{1}{T} \int_0^T p(t)\, dt
$$

A second measure of the observed noise is the Time Probability Distribution (TPD). This function can be obtained from the data in the following manner. We select a threshold power level P_o and from the arrival times of the noise impulses, we construct the function

$$
\begin{aligned}
P(t) &= 1 \qquad \text{for } P(t) > P_o \\
&= 0 \qquad \text{for } P(t) < P_o
\end{aligned}
$$

This eliminates all information regarding the power in each impulsive event whose distribution has already been defined by the APD. From the function P(t) we compute the normalized autocorrelation function

$$
A(\tau) = \frac{\int_0^T P(t).P(t-\tau).dt}{\int_0^T P(t).P(t).dt}
$$

This function has the desired property that it counts up the number of occurrences for which the pulse spacings above the threshold power P_o are separated by a time interval T. By normalizing the function A(T) computed for a particular threshold by the total number of crossings of the signal at P_o, the relative frequency of occurrences of pulses at a separation T can be determined. The TPD may be derived from A(T) by integrating A(T)

$$\mathrm{TPD}(T > t) = 100\% \; \frac{\int_T^{\infty} A(t)dt}{\int_0^{\infty} A(t)dt}$$

which now gives the percentage of time that the pulse spacings at a given threshold exceed the time t.

INTERPRETATION

The average background power at 165 kHz on June 8-9, 1983 is displayed in Figure 8. The background is highly non-uniform over a period of 24 hours and also varies from day to day. Sunrise and sunset occurred at approximately 6:00 and 20:30 EST; and as Figure 8 indicates, these diurnal events consistently correspond to rapid changes in the average noise background. The nighttime level was usually 14 dB higher than the daytime level.

An analysis of the amplitude and time probability distributions provides a valuable tool for studying the statistical characteristics of the background noise. For example, if the noise has a Rayleigh distribution we should see an APD with the form

$$N(P > P_s) = \text{Constant} \times \exp(-.694\ P/P_s)$$

where P represents the threshold power level and P_s is the half-power width of the distribution function. We have selected three typical samples of data to represent daytime, nighttime, and thunderstorm noise properties (Figure 9) to be used in our analysis. A comparison of the theoretical curve with a typical, daytime APD from a single .833 second sample (Figure 10) shows that the noise follows a Rayleigh distribution below a threshold of $1.1\text{x}10^{-17}\text{W/m}^2\text{Hz}$, a value that is 6 times the average power level for the sample. Above this threshold, there are noticeably more impulsive events than predicted from the Rayleigh statistics. In Figure 10 we also show the APD for a .833 second sample for the nighttime period on the same day. Here we see that the data is Rayleigh distributed below a threshold of $1\text{x}10^{-17}\text{W/m}^2\text{/Hz}$, once again a value that is 6 times the average power for that sample, and is noticeably non-Rayleigh above this threshold. The average noise level differs by a factor of 5-10 between these two samples, which accounts reasonably well for the difference between the two threshold levels. A comparison of the day/night APDs shows that the nighttime distribution is significantly flatter. The number of events exceeding 6 times the average noise level is much higher in the nighttime sample than in the daytime sample.

A comparison of the day/night APD with the APD from a sample taken during a thunderstorm on May 26 (Fig. 10) shows a much different character, however. The thunderstorm APD shows a greater frequency of impulsive events between 2 and 17 times the average background level than expected from Rayleigh statistics.

The predicted TPD, assuming that the arrival rate is completely uncorrelated, can be expressed as a gaussian process

$$P(t > T) = \exp(-NT)$$

where N is the average arrival frequency. We may interpret the observed TPDs by comparing them to this model of a completely uncorrelated pulse arrival distribution which yields a straight line in Figure 11 with a slope of -1. We see that when the threshold is set to zero as in curve 'A', the arrival rates remain uncorrelated for time intervals shorter than 400 ms. Since the full record length is only 833 ms, we are clearly undersampling pulse intervals separated by times greater than 400 ms. By increasing the record length to 8.3 seconds this limitation can probably be avoided.

We have computed the TPD for two additional thresholds (B and C) which correspond to levels at 3.7 and 1.4 dB below the highest detected peak in each sample. As we see from the daytime and nighttime distributions, as the threshold is increased, the TPD deviates markedly from the case of uncorrelated behavior represented by the dashed lines with slopes of -1. This deviation occurs over an interval of 8 ms to 160 ms. In particular, we see that at the highest threshold, 78% of all observed pulse spacings ought to be separated by 80 ms whereas for the daytime sample (curve C) over 98% of the pulse spacings exceed this interval implying a high degree of correlation. As we see from the data itself (Figure 9), the TPD is biased since the number of threshold crossings is only 5 as compared to 36 for the 3.7 dB level and 5000 for the zero level thresholds.

For threshold B, the TPD shows that impulsive events with intervals less than 16 ms are more strongly correlated in their arrival. There are more of these events observed than expected from a random distribution. Events having spacings longer than this are very nearly completely uncorrelated over the range from 16ms to 300 ms.

For the nighttime sample, the distribution is markedly different. Once again, for intervals greater than 400 ms the undersampling of the data becomes a problem. Generally, the distribution between 16ms and 30ms is uncorrelated at the two highest thresholds as was the case for the daytime sample. For intervals less than 16ms, we once again notice a departure from completely uncorrelated behavior, this time in the direction of fewer such events than predicted.

Evidently, the daytime and nighttime noise, based on a single .833 second sample of average conditions during each period, is quite similar. The pulse interval distributions tend to be uncorrelated between 16 and 300ms. For times shorter than this, the behavior tends to be non-random and correlated. This can be understood if the typical duration of a single impulsive event were $<$16ms so that we are resolving an individual burst of noise. An examination of Figure 9 shows that this is indeed the case.

In Figure 10 we have also determined the TPD for a representative sample of data taken during a thunderstorm on May 26. We see that for spacings shorter than 110 ms, the noise impulses appear to be uncorrelated at all three thresholds, however for intervals between 110ms and 300ms, the distribution is noticeably correlated. An inspection of Figure 9 shows that the noise tends to be clumped at intervals spanning the range 110 to 300 ms. This behavior is far more pronounced than the daytime or nighttime events. This distribution can be explained by lightning discharges consisting of multiple strokes at intervals of .1 to .3 second, each consisting of a random process, perhaps the propagation of pre-discharge leaders. Once again, it should be kept in mind that the above discussion represents the analysis of a single .833 second data sample for a lightning discharge. To what extent this is typical of all such discharges will need to be determined by studying a larger sample of thunderstorms during their entire lifetimes.

The majority of the data recorded and analyzed was at a nominal frequency of 165 kHz. However, between June 13 and June 27 three days of data were recorded with the second channel at 150 kHz and seven days at 180 kHz. An examination of this data shows no significant difference between the two channels indicating no dependence of the noise characteristics on frequency between 150 and 180 kHz.

ACKNOWLEDGMENTS

The authors wish to acknowledge the help of Jay Schwartz, Joel Friedman and Paul Callahan in initiating, designing and analyzing this experiment. The help of L. Quinn of NRL in calibrating the loop antenna is appreciated.

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TABLE I

GWEN PROJECT

LIST OF SIGNIFICANT CHANGES AND SETTINGS IN DATA-TAKING PROCEDURE

5/10/83 - Very preliminary tape - not kept as part of data base

5/13/83 - One-channel test tape.

5/19/83 - Two-channel setup with one wave analyzer (H-P 3590A), two operational amplifiers for different sensitivities. Gain settings as follows:
H-P 461A preamp - 40 dB gain
H-P 3590A wave analyzer: input voltage - 0.03 volts
range - -50 dB.
center frequency - 165.00 kHz
bandwith - 3100 Hz
mode - upper side band
strip chart - 5 volts full scale
H-P 400E power meter - 1 volt
H-P 606B cal. generator - -120 dBm output
operational amplifier gains: channel #0 - X2
channel #1 - X20

5/23/83 - New standard gain settings to prevent saturation:
H-P 461A preamp - 20 dB gain
H-P 3590A wave analyzer: input voltage - 0.3 volts
range - -50 dB.
center frequency, bandwidth and sideband unchanged

5/26/83 - Equipment configuration changed to include two wave analyzers, to increase dynamic range. Sample rate decreased from 10 kHz to 6 kHz, increasing length of one record to 0.83333...seconds. Monitor routine added to ensure that possible "hang-up" of analog-to-digital converter is monitored.
New standard gain settings as follows:
H-P 461A preamp - 40 dB gain
H-P 3590A wave analyzer (high-gain channel): input voltage - 0.1 volts
range - -50 dB.
center frequency - 165.00 kHz
bandwith - 3100 Hz
mode - upper side band
A/D assignment - channel #0
H-P 310A wave analyzer (low-gain channel): input voltage - 10 volts
range - -50 dB.
center frequency - 165.00 kHz
bandwith - 3000 Hz
mode - lower side band
A/D assignment - channel #1
strip chart - 5 volts full scale
H-P 400E power meter - 1 volt
H-P 606B cal. generator - -120 dBm output

operational amplifier gains: channel #0 - X2
channel #1 - X5

note: input voltage ranges of one or both wave analyzers may be lower by a range (X3) in first day or so.

5/27/83 - New calibration routine : rec. #1 - -120 dBm
rec. #2 - -90 dBm

5/31/83 - Software changed to sample a group of 10 records at a time in order to better sample longer τ s. Total group length is now increased to 8.33333...seconds, with about 0.022 sec. inter-record gap, and inter-group interval increased to 10 min. from 1 min.

6/1/83 - Standard inter-group interval increased to 12 minutes.

6/9/83 - Removed 230 kHz low-pass filter and changed from AIL to H-P synthesizer.

6/13/83 - Digitally-controlled attenuator installed to control input range automatically. Most gain settings remain unchanged. Both wave analyzers are now set to input voltages of 0.1 volt and ranges of 50 dB. The 310A (channel #1) is now set at an alternate frequency.
Constants for attenuator algorithm:
upscale trigger - 1024 counts
downscale trigger - 100 counts
wait for downscale - 10000 samples
H-P 310A center frequency set to 150 kHz. No calibration records recorded for remainder of data.

6/14/83 - Calibration tape recorded to calibrate impulse response of wave analyzers, and to measure inter-record interval.

6/17/83 - H-P 310A center frequency changed to 180 kHz.

6/23/83 - Recorded calibration tape for absolute amplitude calibration.

6/28/83 - Algorithm on switched attenuator changed to prevent over-reduction of range, and ensure wide dynamic range. In the new configuration, both wave analyzers are set at a center frequency of 165 kHz, but with the 310A used as a low-gain unit. Settings for the 3590A remain unchanged.
310A settings are: input voltage - 1.0 volts
range - -40 dB
The attenuator set routine now triggers off channel #1, the low-gain channel.

7/8/83 - Data-taking ends

7/12/83 - Frequency response calibration of system.

TABLE II

GWEN PROJECT

LIST OF UNIQUE CHARACTERISTICS OF INDIVIDUAL TAPES

5/13/83 - Test tape with one channel active

5/19/83 - Calibration signal on rec. # 15.

5/24/83 - Calibration signal recorded on recs. # 39 and 40.

5/26/83 - Local thunderstorm observed. A variety of settings used to capture local noise. 404 records recorded before power fail. The tape history is as follows: Tape started at 13:36:00 EDT, just before rain started locally. The storm passed about 5 mi. west at about 13:50-13:55. Initial settings were:

	input voltage	range
3590A	0.3 volts	-50 dB.
310A	10 volts	-50 dB.

No cal. was taken. After rec. #8, the 310A input voltage was changed to 30 volts. After rec. #19, the 310A bandwith was changed to 200 Hz, the 3590A bandwidth to 100 Hz, and the sample rate to 1 kHz (5 sec sample duration). After rec. #43, the sample rate was changed to 500 Hz. After rec. #64, the 310A input voltage was set back to 10 volts. There appears to be a ~ 2 kHz carrier present on narrow bandwidths. Recording continued until rec. #404, when a power fail occurred during a second thunderstorm.

5/27/83 - Data-taking interval set to 5 min. for weekend operation. 650 records recorded before power fail.

5/31/83 - 980 records recorded before power fail.

6/3/83 - Data interval set to 36 min. for weekend. 200 records recorded before power fail.

6/6/83 - The first part of this tape (all data recorded before 02:02:40 on 6/7/83) is no good because of a/d converter hangup. 1040 records recorded before power fail.

6/10/83 - Data interval set to 36 min. for weekend. 350 records recorded before power fail.

6/13/83 - The latter portion of this tape (all after 230 records) is no good because of a/d converter hangup. 380 records recorded before power fail.

6/20/83 - 120 records recorded before power fail.

6/23/83 - Test tape recorded for amplitude calibration.

6/27/83 - 270 records recorded before power fail.

6/30/83 - Tape stopped manually after 1060 records.

7/1/83 - Data interval set to 36 min. for weekend.

7/8/83 - Log unavailable.

Table III - Gwen project - tape log

Notes: General characteristics of data are annoted in previous tables.
On stop times, "+n" means that the tape was stopped at that time n days after the start date.
Distances under TV weather column are to nearest storm front from digital radar.

Date	Start Time E.D.T.	Stop Time E.D.T.	Interval Min.	Local Precip.	TV Weather Info.
5/13/83	16:10:10	10:50:10+1	1	no data	no report
5/14/83	no data			no data	no report
5/15/83	no data			no data	no report
5/16/83	no data			no data	no report
5/17/83	no data			none	no report
5/18/83	no data			none	no report
5/19/83	16:03:30	10:46:30+1	1	0.11" @ 16:00 no thunder	no report
5/20/83	11:03:00	05:45:00+1	1	0.13" @ 02.00	no report
5/21/83	no data			0.43" @ 12:00 no thunder	no report
5/22/83	no data			0.88" from 8:00 to 16:00	no report
5/23/83	12:37:10	07:17:10+1	1	none	160 mi.
5/24/83	09:48:10	04:26:10+1	1	none	710 mi., heavy
5/25/83	no data			none	120 mi., local heavy 1260 mi., nearest front

Table III (Cont'd) - Gwen project - tape log

Date	Start Tim E.D.T.	Stop Time E.D.T.	Interval Min.	Local Precip.	TV Weather Info.
5/26/83	13:36:00	20:20:00	1	local thunderstorms 0.03" @ 15:45 0.60" @ 23:00	D.C. area, heavy
5/27/83	14:59:30	21:09:30+2	5	none	475 mi.
5/28/83	from 5/27			none	825 mi.
5/29/83	from 5/27			0.44" from 02:00 to 11:00 0.13" @ 21:00	100 mi., local
5/30/83	no data			none	D.C. area 120 mi., nearest front
5/31/83	20:31:45	12:51:45+1	10	none	only local showers
6/1/83	12:58:10	11:34:10+1	12	0.01" @ 14:30	195 mi. 1105 mi., heavy
6/2/83	13:55:25	12:19:25+1	12	none	475 mi.
6/3/83	14:03:00	02:03:00+1	36	0.13" @ 19:00	80 mi.
6/4/83	no data			0.26" @ 00:00 trace throughout day	100 mi.
6/5/83	no data			none	315 mi.
6/6/83	02:10:40+1	12:22:40+1	12	none local thunderstorms noted	D.C. area 40 mi., nearest front
6/7/83	15:56:30	14:32:30+1	12	none	80 mi.
6/8/83	15:15:45	13:51:45+1	12	0.03" @ 03:00	630 mi.
6/9/83	14:50:10	13:26:10+1	12	none	160 mi., local heavy no fronts

Table III (Cont'd) - Gwen project - tape log

Date	Start Time E.D.T.	Stop Time E.D.T.	Interval Min.	Local Precip.	TV Weather Info.
6/10/83	14:09:50	11:09:50+1	36	none	510 mi. (E) 1105 mi. (WSW), heavy
6/11/83	no data			none	140 mi., local heavy 590 mi., nearest front
6/12/83	no data			none	160 mi., local 1260 mi., nearest front
6/13/83	16:27:30	21:03:30	12	local thunderstorm activity noted	no report
6/14/83	no data			none	no report
6/15/83	14:49:25	13:25:25+1	12	none	160 mi., local no fronts
6/16/83	13:59:10	12:35:10+1	12	none	no report
6/17/83	14:39:10	13:15:10+1	12	none	80 mi., heavy
6/18/83	no data			0.64" @ 19:00	40 mi.
6/19/83	no data			0.01" @ 18:00	no report
6/20/83	14:18:40	16:42:40	12	0.32" from 14:00 to 20:00	no report
6/21/83	11:24:55	10:00:55+1	12	0.03" @ 08:00 1.32" @ 14:00 0.20" @ 18:00	no report
6/22/83	15:30:00	14:06:00+1	12	none	no report
6/23/83	16:16:45	14:52:45+1	12	none	no report
6/24/83	14:50:40	13:26:40+1	12	none	no report
6/25/83	no data			none	no report

Table III (Cont'd) - Gwen project - tape log

Date	Start Time E.D.T.	Stop Time E.D.T.	Interval Min.	Local Precip.	TV Weather Info.
6/26/83	no data			none	200 mi., local 950 mi., nearest front
6/27/83	14:07:40	19:31:40	12	none	160 mi., semi-local no fronts
6/28/83	12:45:45	11:21:45+1	12	none	D.C. area
6/29/83	13:34:10	12:10:10+1	12	0.08" @ 07:00	710 mi.
6/30/83	14:50:10	12:02:10+1	12	none	275 mi., semi-local no fronts
7/1/83	12:03:30	07:51:30+3	36	none	no report
7/2/83	from 7/1			none	120 mi., local no fronts
7/3/83	from 7/1			none	no report
7/4/83	from 7/1			0.22" @ 20:00	no report
7/5/83	15:31:40	14:07:40+1	12	0.19" @ 16:00	195 mi., heavy
7/6/83	16:28:00	15:04:00+1	12	none	no report
7/7/83	15:56:45	14:32:45+1	12	none	no report
7/8/83	14:44:40	10:32:40+3	36	no report	no report
7/9/83	from 7/8			no report	no report
7/10/83	from 7/8			no report	2050 mi., semi-local
7/11/83	data ends			no report	no report

GWEN RECEIVER BLOCK DIAGRAM AS OF 5/19/83

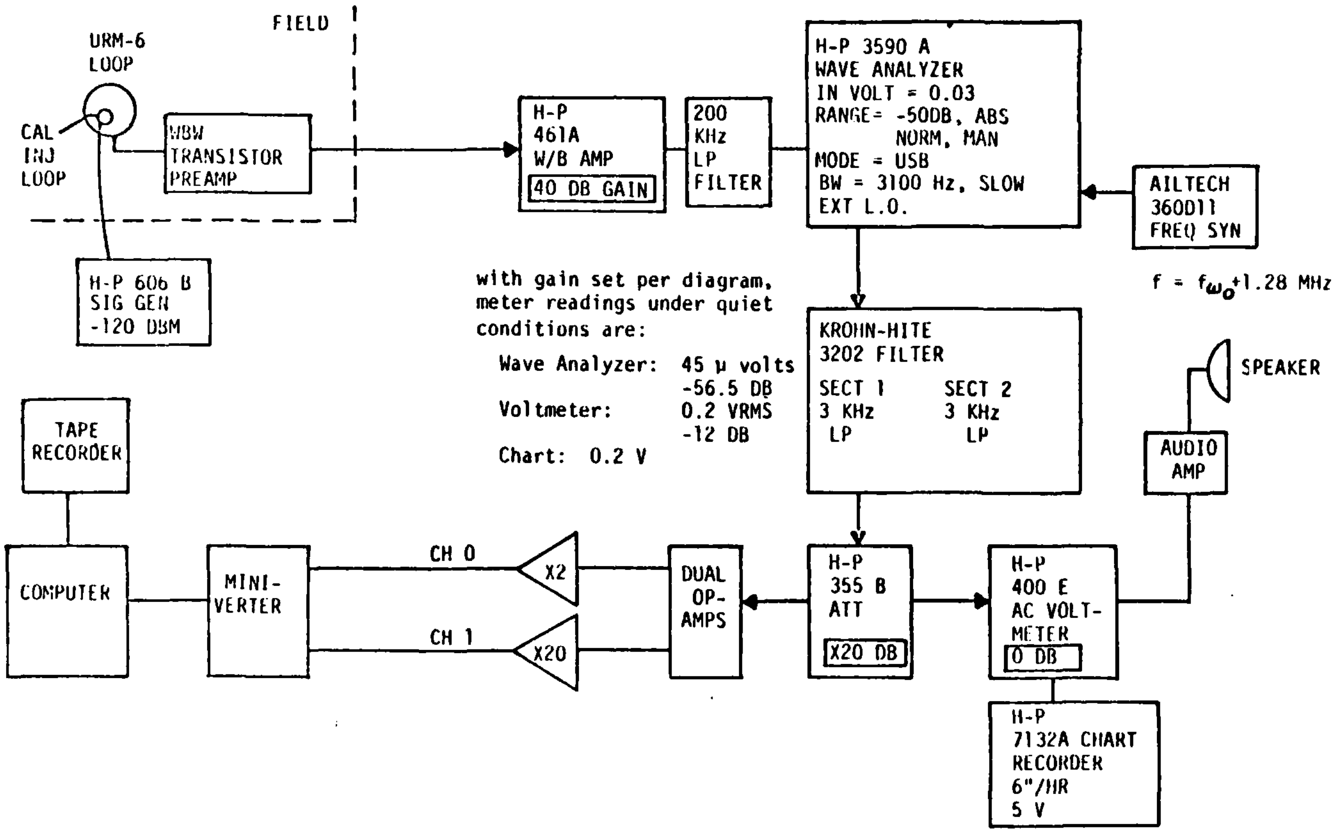

Figure 1 - System A. Noise recording equipment setup as of 5/19/83.

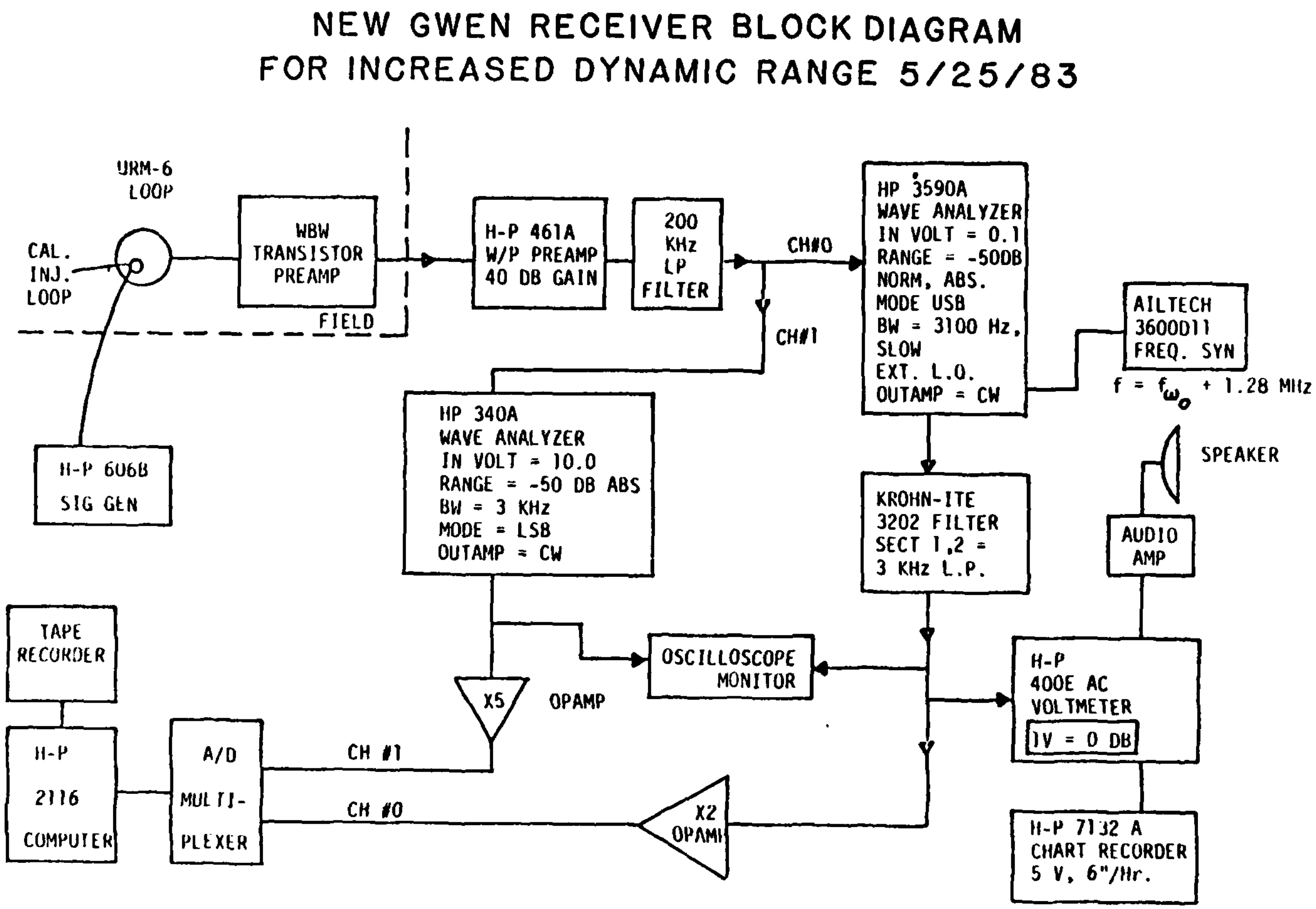

Figure 2 – System B. Changes as of 5/25/83. Two wave analyzers are now used to increase dynamic range.

GWEN RECEIVER MODIFICATIONS AS OF 6/13/83
(MONITORING SYSTEM UNCHANGED)

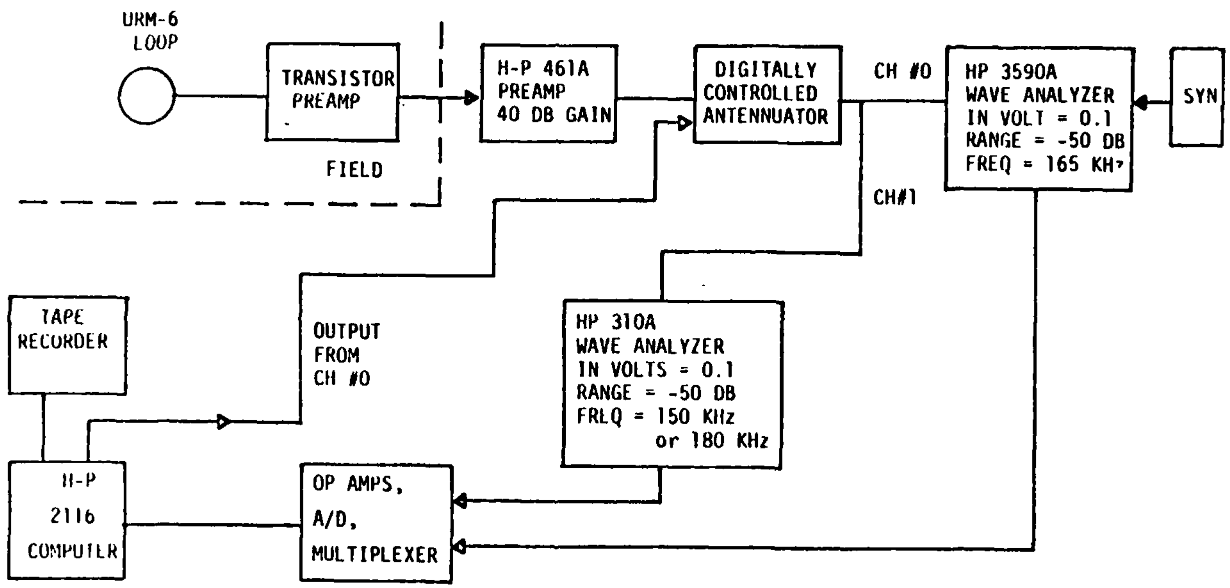

Figure 3 - System C. Changes as of 6/13/83. A digitally-controlled attenuator is used to further increase dynamic range. The second wave analyzer is used to sample a different frequency within the band of interest.

GWEN RECEIVER MODIFICATIONS AS OF 6/28/83

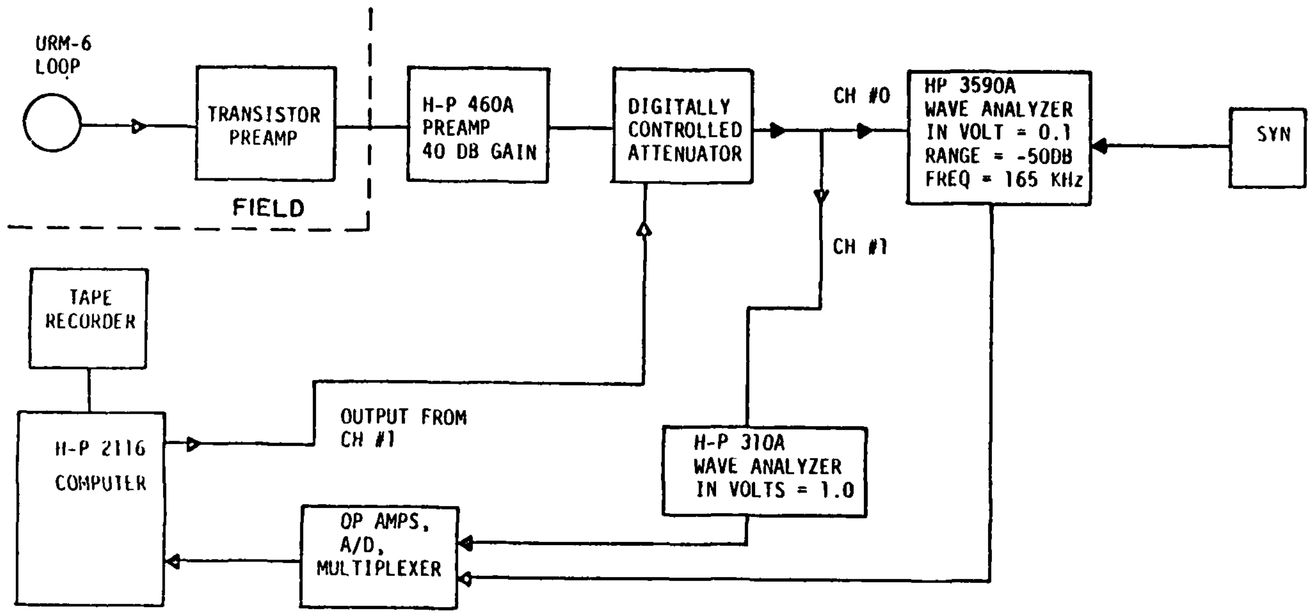

Figure 4 - System D. Changes as of 6/28/83. The digitally-controlled attenuator is still used but is now set to sample the second wave analyzer which is reset to 165 kHz. The first analyzer is now set to a higher gain so that the lower-amplitude portion of the noise can be observed.

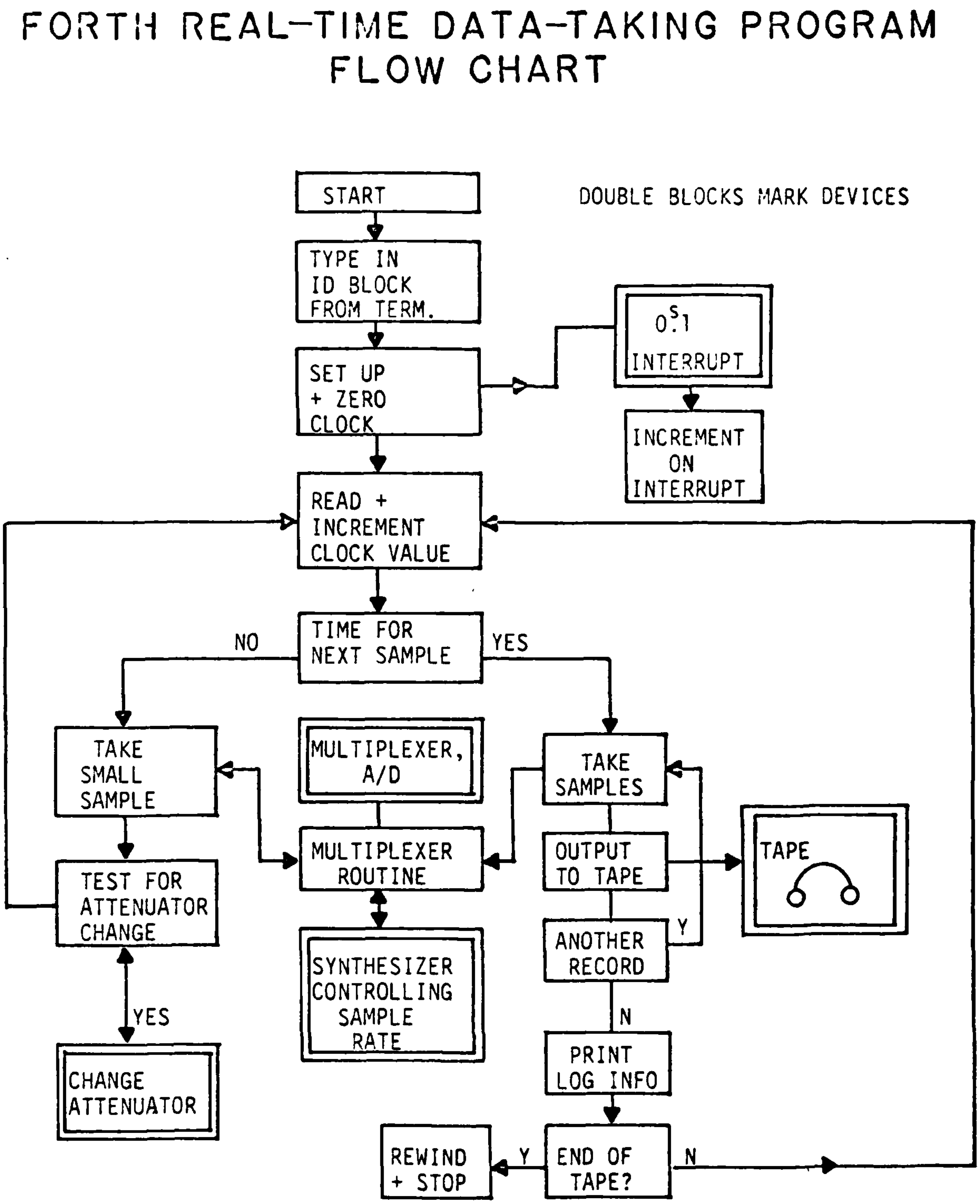

Figure 5 - Forth real-time data-taking program block diagram.

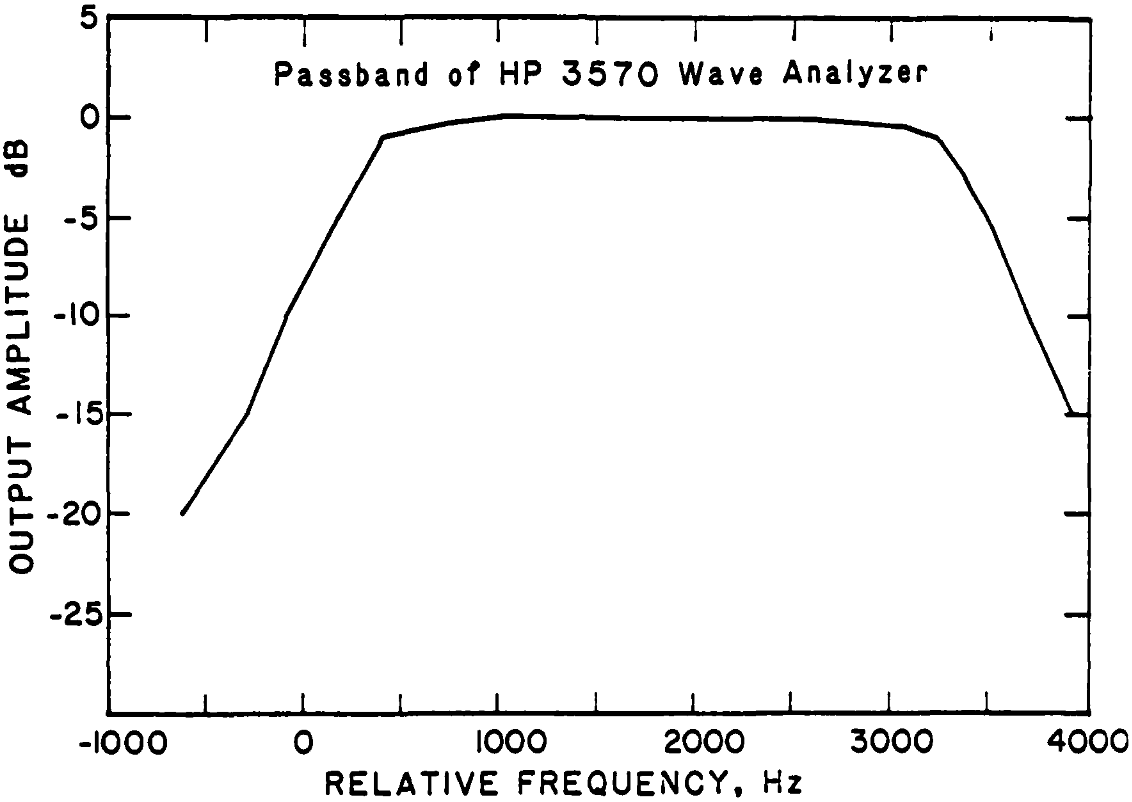

Figure 6 - Measured i.f. passband of the Hewlett-Packard Model 3590A wave analyzer used. Setting was 3100 Hz bandwith, upper sideband.

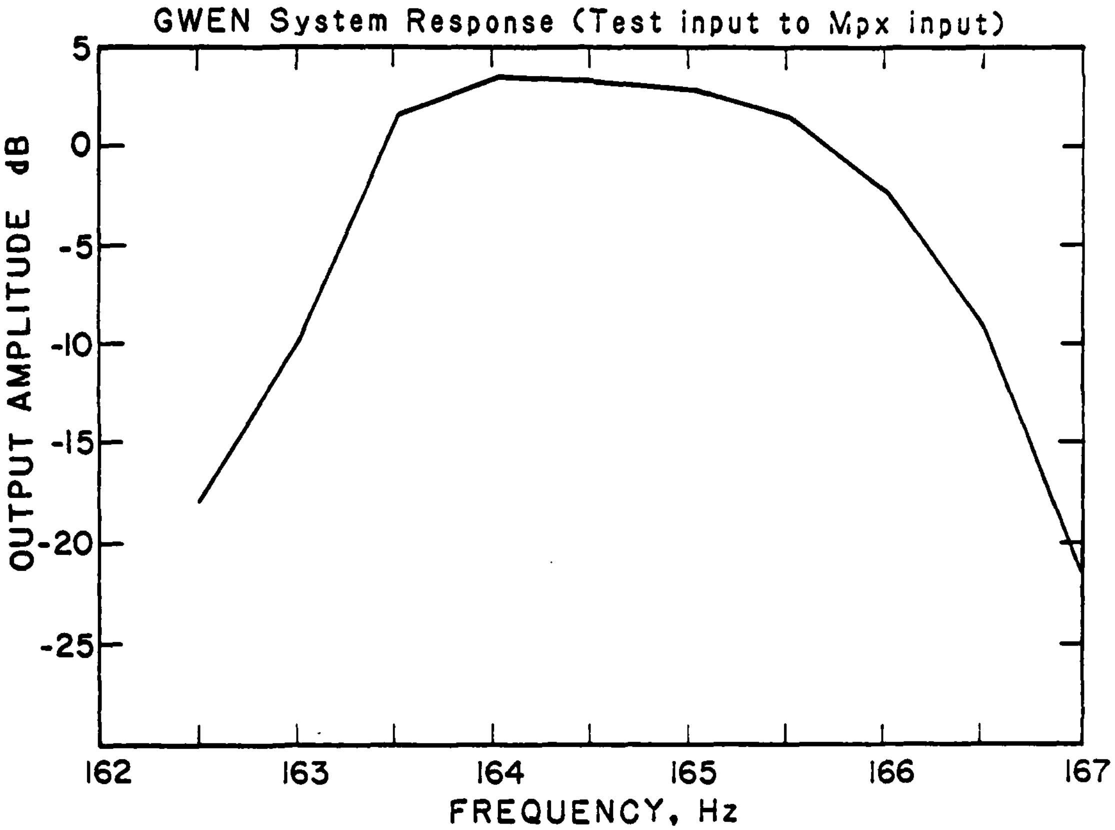

Figure 7 - Measured passband of noise recording system from test input to multiplexer input. Center frequency set to 165.0 kHz.

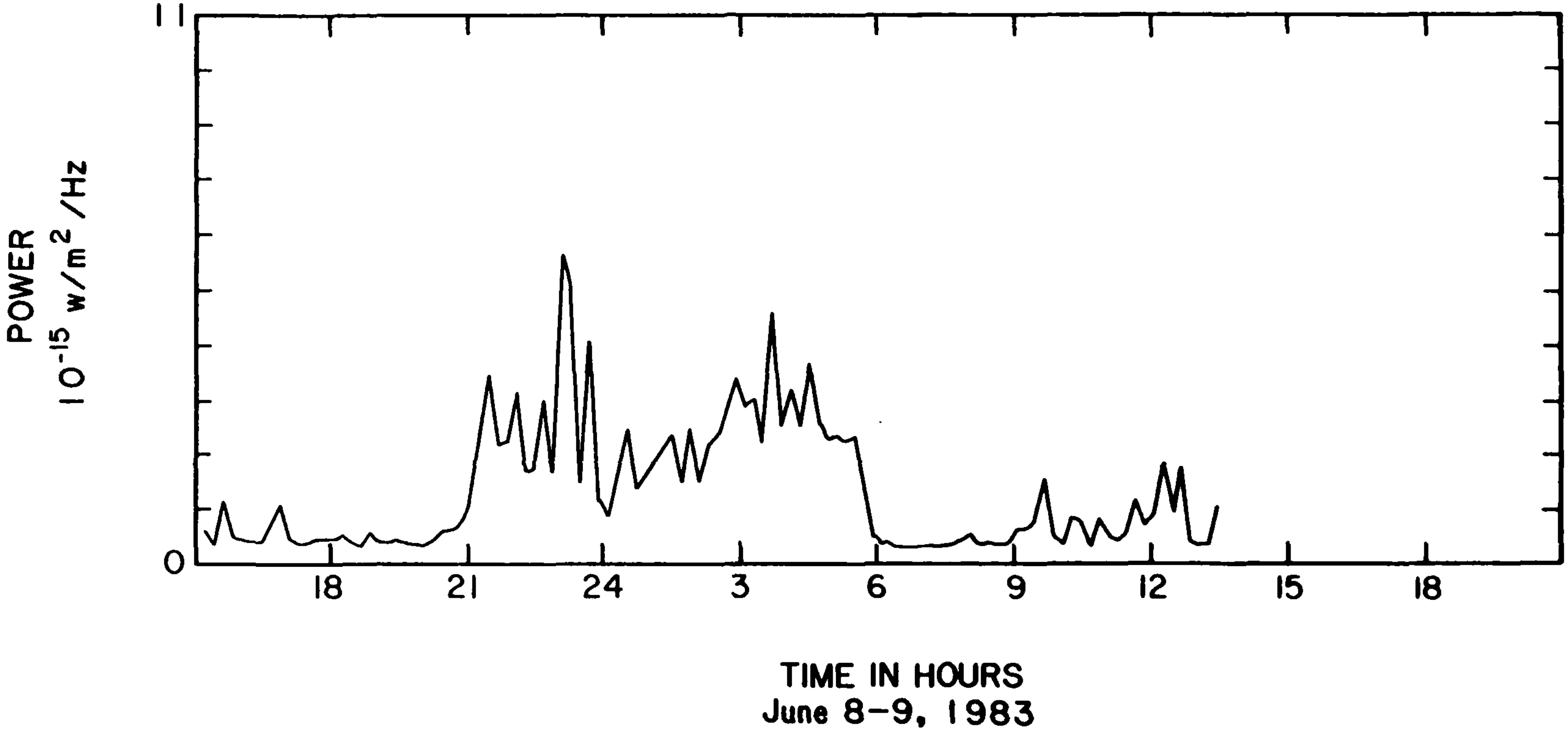

Figure 8 - Example of variation in mean noise level over 24 hour period at 165 KHz..

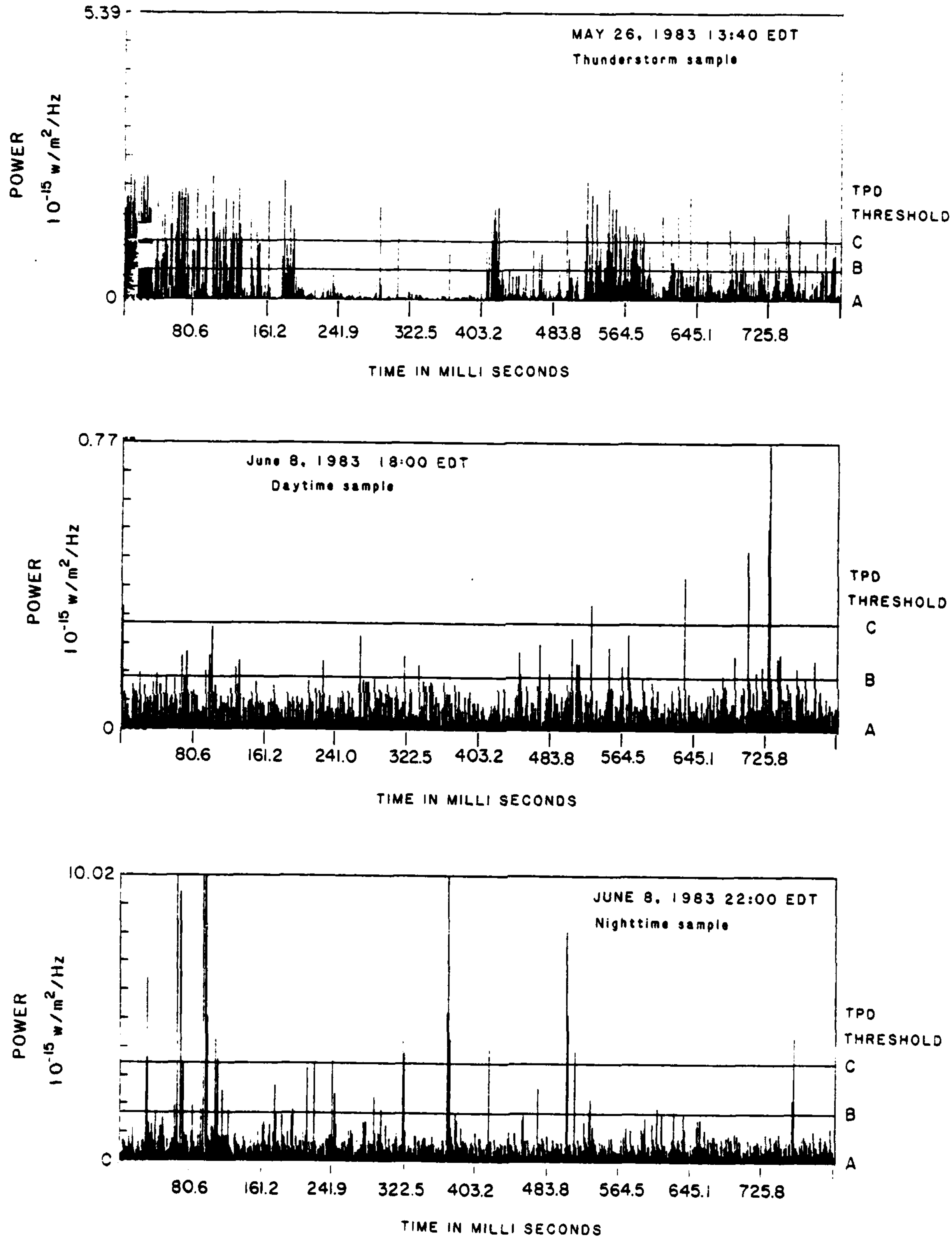

Figure 9 - Single-record signal amplitude (no averaging) for daytime, nighttime, and thunderstorm samples taken on June 8 and May 26.

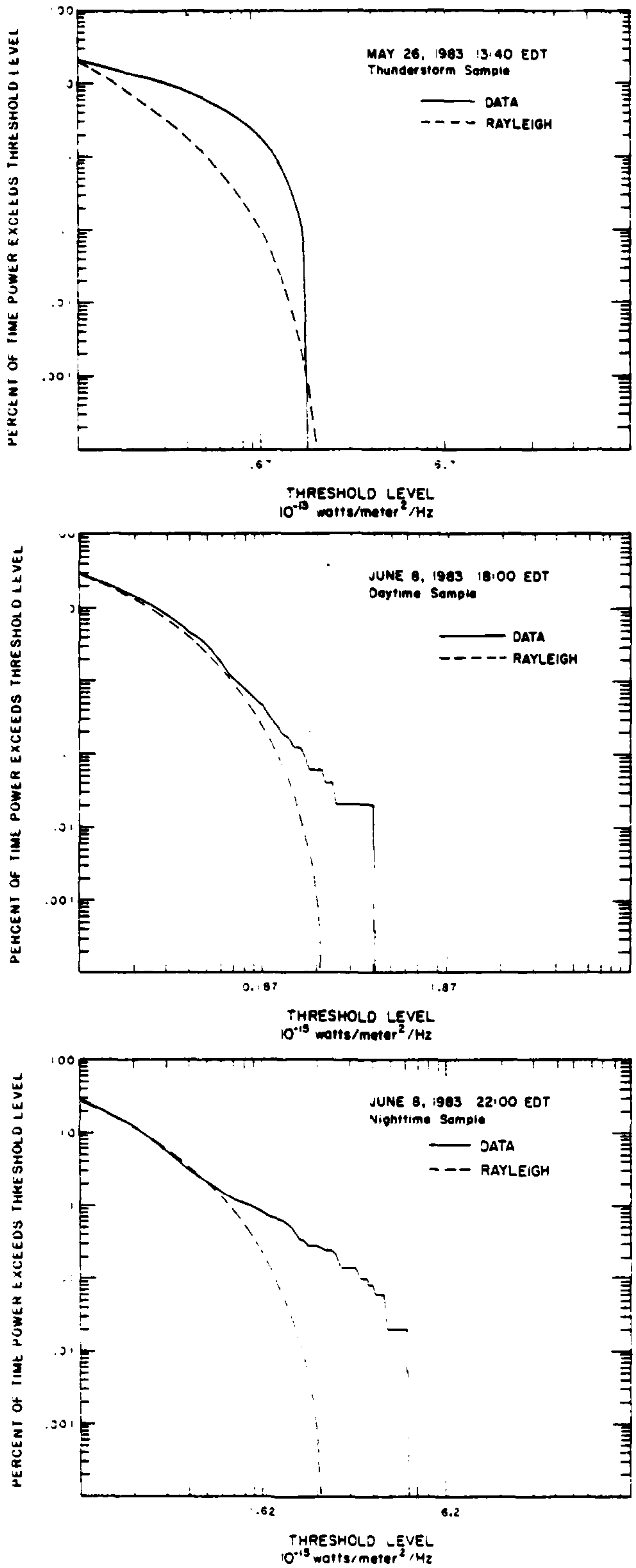

Figure 10 - Amplitude probability distributions for the data in Figure 10. The X's represent the curve expected from a Rayleigh amplitude distribution.

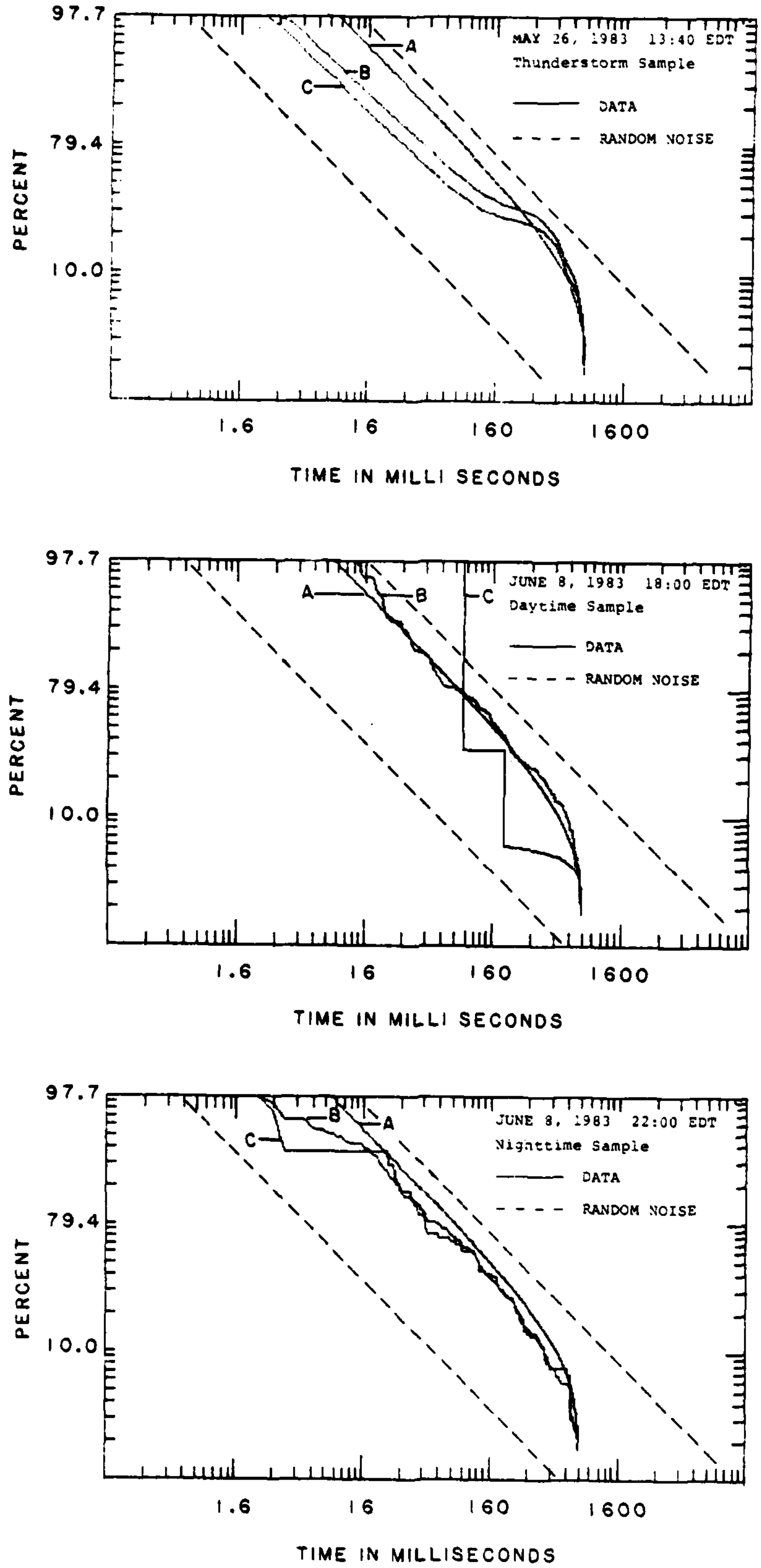

Figure 11 - Time probability distributions for the data in Figure 10.

APPENDIX A

I. Discussion of Programs Used in Noise Analysis

The tape which is written by the on-site HP-2116C mini-computer consists of approximately 1130 records, each containing 10,000 data samples followed by a 20 word identification section. The output voltages from the two receivers have been digitized as one 16-bit word per data sample for each receiver. Since the two receiver outputs (R1 and R2) have been multiplexed, alternate data samples in each record correspond to the output from each receiver. Successive samples from the same channel are separated in time by the sample rate as indicated in the data log. The A/D converter used produces an output number consisting of 11 bits plus sign (range -4096 to +4096). The right-hand 4 bits in each 16 bit word are "garbage", and must be discarded by arithmetically shifting each sample 4 bits to the right (equivalent to a divide by 16). This pecularity was not eliminated at the source computer because of timing constraints caused by the high data rate.

```
1     2     3          9997    9998    9999   10000
*****************    ***********************************************************

R1    R2    R1   ...   R1      R2      R1      R2      ABCDEFGHIJKLMNOPQRST

*****************    ***********************************************************

            RECORD     N                               I. D. SECTION
```

The ID section contains the start time for each record together with the date, attenuator setting, time interval between samples and the frequency that was monitored. Table A1-1 (p. 65) gives a detailed summary of the information contained in the ID record. All tapes are 9-track, 800 bpi., with no pre- or post-ambles or tape label.

During the data processing phase, an entire data tape is read into a VAX 11/780 disc file in order to reduce the processing time per tape.

Table A1-1. The Identification Section

Word Number	Label	Identification
10001	A	Time in .1 second intervals since start of tape (sign bit is a data bit)
10002	B	Time since start of tape in multiples of 6553.6 seconds.
10003	C	Year.
10004	D	Month.
10005	E	Day (Eastern Daylight Time).
10006	F	Hour.
10007	G	Minute.
10008	H	Second.
10009	I	Monitoring frequency in kHz.
10010	J	Bandwith in Hz.
10011	K	Location # (always 1).
10012	L	Antenna orientation (always 0 degrees)
10013	M	Time interval between groups in units of 0.1 seconds.
10014	N	Record count, starting with 1 at start of tape.
10015	O	# of records in group.
10016	P	Attenuation setting used (1,2,4 or 8).
10017	Q	Spare.
10018	R	"
10019	S	"
10020	T	"

A. PROGRAM NOISE

This program reads each record from the VAX data file through the code combination:

```
        CHARACTER BUFFER*32768
        BYTE JDATA(32768)
        EQUIVALENCE (JDATA,BUFFER)
              ****
              ****
        OPEN (UNIT=1,CARRIAGECONTROL='LIST',STATUS='UNKNOWN',RECORDSIZE=20040)
              ****
              ****
        READ(1,5,END=1004) BUFFER
5       FORMAT(A)
              ****
              ****
        CLOSE(UNIT=1)
```

An entire record, consisting of 20040 bytes, is read into an array called BUFFER. The HP-2116C writes a 2-byte data word onto tape with the least significant byte first. Since the VAX 11/780 tape I/O software expects to see the most significant byte first, the byte order in each of the 10020, 2-byte words must be reversed. This operation is accomplished by a call to the subroutine DECODE. Here, the byte order is swapped using a MACRO routine called BYSWAP. The resulting 2-byte word is then passed back to the main program through the INTEGER*2 array JDATA. In addition, the contents of the ID record are stored in the array IDREC and the record date and start time is converted into 'year, month, day, hour, minute, second' format.

The contents of the first 100 data samples are tested against the corresponding data words in the previous record to insure that record duplication has not occurred. This would be the case if the multiplexer malfunctioned. The current record would then be ignored in subsequent data analysis. For the first record of each tape, the corresponding power level from each receiver output is determined by squaring the digital value of each data sample in the record and multiplying by a calibration constant. This background power, in units of 10^{-15}W/m^2, is then plotted as a function of time for the first record.

The statistical characteristics of a particular record are determined in a subroutine called STAT. The Digitally-Controlled Attenuator has 4 states (1, 2, 4, 8 in ID word 'P') and the ID record identifies which of the 4 is operative at the time a record was taken. The attenuation is compensated for in the statistical analysis by dividing the digitized voltages in each record by the factors corresponding to the appropriate attenuation step, namely 1.0, .0631, .00668, .000708. The resulting values are then squared and multiplied by the calibration constant appropriate to each receiver, measured at the attenuation setting of 1.0 to determine the instantaneous power. The quantities that are determined for each record and for each receiver output are:

1) $$\langle |V| \rangle = \frac{1}{5000} \sum_{i=1}^{5000} |V_i|$$

2) $$\langle V^2 \rangle = \frac{1}{5000} \sum_{i=1}^{5000} V_i^2$$

3) $$P_m = \text{Max} \frac{V_i^2}{\langle |V| \rangle}$$

4) $$V_D = 20. \text{ Log} \left(\frac{\langle V^2 \rangle^{1/2}}{\langle |V| \rangle} \right)$$

For the data taken after June 15, 1983, only P_m , the highest noise spike found in a record, was determined. The quantity V_d is a measure of the impulsiveness of the noise in a given record. The quantities $\langle P \rangle$, V_D and P_m are thereby determined for each record and plotted as a function of local civil time.

B. Program APD

The Amplitude Probability Distribution (APD) is determined by reading a data record, compensating for any attenuation changes, and computing the percentage of time in a single record that the background noise exceeded a prescribed threshold. The average background power level $\langle P \rangle$ of each receiver is computed and a total of 100 threshold levels are determined by simple multiples of $\langle P \rangle$. The number of data samples exceeding each threshold is then found. The result is then plotted, for a single record, on a Log-Log graph.

C. Program TPD

Once a particular record has been selected from the data file, a Time Probability Distribution (TPD) is computed as follows: The detected background power P for each data sample is corrected for the attenuation as in previous programs. A threshold power level, T_o, is selected and a function P is defined such that,

$$\tilde{P}_i = 1 \quad \text{for } P_i > T_o$$
$$= 0 \quad \text{for } P_i < T_o$$

where i is the index of the data sample in each record. Given this function $\tilde{P}_i$, the autocorrelation function A(j) is computed

$$A(j) = \frac{\sum_{i=1}^{5000} \tilde{P}_i \quad \tilde{P}_{i+j}}{\sum_{i=1}^{5000} \tilde{P}_i \quad \tilde{P}_i}$$

where j corresponds to the offset period τ in the integral definition of the autocorrelation,

$$A(\tau) = \int_0^{\infty} P(t)*P(t-\tau)dt$$

This function is a measure of the fraction of noise pulses above the threshold power T_o that have a separation in time of j x .16 milliseconds. The TPD is related to the autocorrelation function A(j) by

$$T(>k) = \frac{\sum_{j>k}^{5000} A(j)}{\sum_{j=1}^{5000} A(j)}$$

where A(j) is the total percentage of pulses above the threshold and the quantity that is actually plotted on the Log-Log vs Log graph is

$$-\text{Log}_{10}(\text{Log}_{10}(\frac{1}{T(>k)})).$$

```
 OK
270 272 ALIST
BLOCK     270 (416B)
( GWEN SAMPLING ROUTINE )
INTERRUPT 285 LOAD ( TBG ) 3 TBGSTART FP GOODIES FSQRT ASK
2 CONSTANT #CH
10000 CONSTANT LBUF LBUF #CH / CONSTANT NSQ
LBUF 20 + ()DIM OBUF 0 OBUF LBUF + CONSTANT IDBLOCK
280 LOAD ( 9-TRACK )  271 LOAD ( MINIVERTER DRIVER )
0 OBUF SAD ! LBUF 20 + NLOC !
275 LOAD ( ID WORDS )
272 LOAD 8 FLD !
PWRRESET
;S

BLOCK 271 (417B)
( MINIVERTER DRIVER FOR GWEN WITH AUTOCYCLE )
BASE @ OCTAL 17 CONSTANT MX 22 CONSTANT OBSLOT
0 VARIABLE MAD 0 VARIABLE NSP
CODE SAMP S ) 0 LD, 0 TC, NSP 0 ST, S1 ) 0 LD, MAD 0 ST,
20000 # 0 LD, MX OTA, MX STC, ,C BEGIN MX SFS, END
BEGIN 0 CLF, OBSLOT STC, ,C BEGIN OBSLOT SFS, END
OBSLOT CLC, ,C
100017 # 0 LD, 7 OTA, MAD 0 LD, 100000 # IOR, 3 CLC,
3 OTA, #CH MINUS # 0 LD, 3 STC, 3 OTA, 40000 # 0 LD, MX OTA,
MX STC, ,C 7 STC, ,C 0 STF, MAD 0 LD, #CH # 0 AD, MAD 0 ST,
NSP ISZ, END 2POP ,
7 !CODE UPEX 7 CLF, JMP,   BASE !
;S

BLOCK 272 (420B)
( GWEN COVER PROGRAM )
10 VARIABLE NREC
: FILLARR 0 OBUF NSQ SAMP ;
276 LOAD 273 LOAD
: DOIT NREC @ 0 DO FILLARR TWRITE LOOP ;
: WAIT 400 0 DO LOOP ;       ( ABOUT 20 MS. )
: DOLOTS TOD @ IDBLOCK ! TOD 1+ @ IDBLOCK 1+ ! IDBLOCK 14 + @
0 DO  FILLARR TWRITE WAIT LOOP ;
: PRPARAM CR 20 0 DO IDBLOCK I + @ S. LOOP ;
: INTTEST BEGIN TOD @ IDBLOCK @ - DUP 0< IF 32768 + THEN
IDBLOCK 12 + @ 1 - > IF 1 ELSE GTEST 0 THEN END ;
: DOTAPE IDSET REW GAP 10000 0 DO INTTEST
DOLOTS PRPARAM FINDSTATS EOT? IF WFM RWO ABORT THEN LOOP ;
;S
```

```
BLOCK 273 (421B)
( A/D ARRAY DUMP, & OTHER GOODIES )
: A/DDUMP 50 0 DO I 2 * OBUF @ 16 / . I 2 * 1+ OBUF @
16 / . CR LOOP ;
1000 VARIABLE TESTAMP
: SCANARRAY 0 NSQ 0 DO I 2 * OBUF @ ABS TESTAMP @ > IF 0= LEAVE
THEN LOOP ;
: WAITFORBURST BEGIN FTHARR SCANARRAY END ;
: ALARM REW IDSET 10000 0 DO WAITFORBURST TWRITE EOT? IF
WFM RWD ABORT THEN LOOP ;
0 VARIABLE MAX 0 VARIABLE MIN 0. REAL AVG
: FINDSTATS 2 0 DO 0 MAX ! 0 MIN ! 0. AVG F! 500 0 DO
I 2 * J + OBUF @ 16 / DUP MAX @ > IF DUP MAX !
ELSE DUP MIN @ < IF DUP MIN ! THEN THEN SFLOAT FSQ AVG F+!
LOOP CR I . AVG F@ NSQ SFLOAT F/ FSQRT F. MAX @ S. MIN @
S. LOOP ;
-->

BLOCK 274 (422B)
( MORE GWEN GOODIES )
: PWRRESET SEL CLR 3 TBGSTART 1 ATTSET ;
;S

BLOCK 275 (423B)
( ID BLOCK SETUP FOR GWEN DATA )
: TSET ." YR?" SASK IDBLOCK 2 + !
." MONTH?" SASK IDBLOCK 3 + ! ." DAY?" SASK IDBLOCK 4 + !
." HR?" SASK IDBLOCK 5 + ! ." MIN?" SASK IDBLOCK 6 + !
." SEC?" SASK IDBLOCK 7 + ! 0 TOD ! 0 TOD 1+ ! ;
: LOGSET ." FREQ?" SASK IDBLOCK 8 + !
." BW?" SASK IDBLOCK 9 + ! ." LOCATION?" SASK IDBLOCK 10 + !
." ANT. ORIENTATION?" SASK IDBLOCK 11 + !
." SAMPLING INTERVAL?" SASK IDBLOCK 12 + !
." # OF RECORDS?" SASK IDBLOCK 14 + ! ;
: IDSET TSET LOGSET 16 IDBLOCK + 4 AZERO ;
;S
```

```
BLOCK 276 (424B)
( DIGITALLY CONTROLLED ATT. DRIVER )
20B CONSTANT ATTCH 1 VARIABLE ATTVALUE 100 DIM DBTEST
10000 CONSTANT DWNINT 0 VARIABLE DOWNCT
CODE ATTSET S ) 0 LD, ATTCH OTA, POP ,
: APRT CR ." ATT. SETTING CHANGED TO " ATTVALUE ? ;
: TATSET TOD @ DOWNCT ! ;
: ATTSET DUP ATTSET ATTVALUE ! ;    1 ATTSET
: ATTUP ATTVALUE @ DUP 8 < IF 2 * ATTSET APRT
TATSET ELSE DROP THEN ;
: ATTDOWN ATTVALUE @ DUP 1 > IF 2 / ATTSET APRT
TATSET ELSE DROP THEN ;
1024 CONSTANT UPTEST 200 CONSTANT DOWNTEST
: UPFLG 0 50 0 DO I 2 * DBTEST @ ABS UPTEST > IF 0= LEAVE THEN
LOOP ;
-->

BLOCK 277 (425B)
( MORE DIGITALLY CONTROLLED ATT. DRIVER )
: DOWNFLG 1 50 0 DO I 2 * DBTEST @ ABS DOWNTEST > IF 0=
LEAVE THEN LOOP ;
: DOTEST 0 DBTEST 50 SAMP ;
: DOTEST DOTEST 100 0 DO I DBTEST @ 16 / I DBTEST ! LOOP ;
: LAZY TOD @ DOWNCT @ - DUP 0< IF 32768 + THEN DWNINT >
IF 1 ELSE 0 THEN ;
: GTEST DOTEST UPFLG IF ATTUP ELSE DOWNFLG IF LAZY IF ATTDOWN
THEN THEN THEN ATTVALUE @ IDBLOCK 15 + ! ;
;S

BLOCK 278 (426B)
( MINIVERTER DRIVER FOR GWEN )
BASE @ OCTAL 2 CONSTANT #CH 17 CONSTANT MX 22 CONSTANT OBSLOT
0 VARIABLE MAD 0 VARIABLE NSP
CODE SAMP S ) 0 LD, 0 TC, NSP 0 ST, S1 ) 0 LD, MAD 0 ST,
BEGIN 0 CLF, OBSLOT STC, ,C BEGIN OBSLOT SFS, END
OBSLOT CLC, ,C 20000 # 0 LD, MX OTA, MX STC, ,C HERE MX SFS,
JMP, 100017 # 0 LD, 7 OTA, MAD 0 LD, 100000 # IOR, 3 CLC,
3 OTA, #CH MINUS # 0 LD, 3 STC, 3 OTA, 40000 # 0 LD, MX OTA,
MX STC, ,C 7 STC, ,C 0 STF, MAD 0 LD, #CH # 0 AD, MAD 0 ST,
NSP ISZ, END 2POP ,
7 !CODE UPEX 7 CLF, JMP,   BASE !
;S
```

```
BLOCK 280 (430B)
( DIGIDATA 9-TRACK ROUTINES ) BASE @ OCTAL
23 CONSTANT MTD MTD 1+ CONSTANT MTC
23 VARIABLE RCD 31 VARIABLE WCD 0 VARIABLE BOB
CODE STATUS MTC LIA, PUSH ,
: BUSY? BEGIN STATUS 1410 AND 0= END ;
: PE? STATUS 2 AND 2 / ;
: REJ? STATUS 10 AND 10 / ; : EOT? STATUS 40 AND 40 / ;
: BOT? STATUS 100 AND 100 / ; : EOF? STATUS 200 AND 200 / ;
: RING? STATUS 4 AND 4 / 1 XOR ;
: LOCAL? STATUS 1 AND ; : TRANSB? STATUS 1000 AND
1000 / ; : REW? STATUS 2000 AND 2000 / ;
CODE CMMD S ) 0 LD, MTC OTA, MTC STC, ,C POP ,
CODE MTB MTC CLC, ,C MTD CLC, ,C 1510 # 0 LD, MTC OTA,
NEXT ,
-->

BLOCK 281 (431B)
( MORE 9-TRACK )
: GAP 15 CMMD BUSY? ; : FSR 3 CMMD BUSY? ; : BSR 41 CMMD
BUSY? ; : RWO 105 CMMD ; : REW 101 CMMD BUSY? ; : CLR 110 CMMD ;
 : SEL 1400 CMMD ; : WFM 211 CMMD BUSY? ;
: FSF 203 CMMD BUSY? ; : BSF 241 CMMD BUSY? ; : GFM 215 CMMD
BUSY? ;          SEL CLR
BUF @ VARIABLE SAD 1001 VARIABLE NLOC
CODE TREAD MTD # 0 LD, 6 OTA, 2 CLC, 100000 # 0 LD, SAD 0 AD,
2 OTA, 2 STC, NLOC 0 LD, 0 TC, 2 OTA, RCD 0 LD, BOB IOR, MTC
OTA, MTC STC, ,C MTD STC, ,C 6 STC, ,C NEXT ,
CODE TWRITE MTD # 0 LD, 6 OTA, 2 CLC, SAD 0 LD, 2 OTA,
2 STC, NLOC 0 LD, 0 TC, 2 OTA, WCD 0 LD, BOB IOR, MTC OTA, MTC
STC, ,C MTD STC, ,C 6 STC, ,C NEXT ,
6 !CODE TPI 6 CLC, MTD CLC, ,C MTC CLC, JMP,
1 +BLOCK CONTINUED
```

[illegible]

```
( STILL MORE [illegible] )
DECIMAL [illegible] 13 + [illegible] CONSTANT [illegible] DECIMAL
: TREAD BUSY? TREAD ; : TWRITE BUSY? TWRITE 1 TREC +! ;
: REW REW 0 TREC ! ; : RWO RWO 0 TREC ! ;
: BTREAD BUF @ SAD ! 10010 NLOC ! TREAD ;
: BTWRITE BUF @ SAD ! 1001 NLOC ! TWRITE ;
: #BLK PREV @ ! ;
: BIN 0 BOB ! ; : BCD 100000 BOB ! ;
: PE? PE? IF 7 EMIT ." ?T " THEN ;
: BTWRITE FSF BSR BTWRITE WFM WFM BSF BSR ;
: BNO PE? PREV @ ? STATUS O. ;
: MSR DUP 0< IF MINUS 0 DO BSR LOOP ELSE 0 DO FSR LOOP THEN ;
: MSF DUP 0< IF MINUS 0 DO BSF LOOP ELSE 0 DO FSF LOOP THEN ;
BASE ! ;S
```

BLOCK 283 (433B)

BLOCK 284 (434B)

BLOCK 285 (435B)

```
( TIME BASE GENERATOR ROUTINES )
BASE @ DUP OCTAL 10B CONSTANT TCH
FIND !CODE 0= IFTRUE INTERRUPT IFEND
CODE TBGSTOP TCH CLC, NEXT ,
TBGSTOP
CODE TBGSTART TCH CLC, S ) 0 LD, TCH DUP OTA, STC, ,C POP ,
 0 VARIABLE TOD , 0 VARIABLE ELT
TCH !CODE TBGINT TCH CLF , TOD ISZ, DUP DUP JMP, TOD 1+ ISZ,
JMP, JMP,
: SWB TOD @ ELT ! ; : SWP TOD @ ELT @ - . ;
BASE !
;S
TBG STARTED BY N TBGSTART
INTERVAL IS 1 SEC / (10 ^ [4-N] )
I.E., 4 IS 1 SEC, 1 IS 1 MILLISEC, ETC.
```

BLOCK 286 (436B)

BLOCK 287 (437B)

```
BLOCK 288 (440B)
( POWER FAIL RESTART )
BASE @ OCTAL FIND !CODE 0= IFTRUE INTERRUPT IFEND
2 ()DIM REGS
SUBROUTINE PUP 4 STC, 0 REGS 0 LD, 1 REGS 1 LD,
0 STF, 5240 JMP, 2 REGS ) JMP,
4 !CODE PDN 4 SFC, IF ' REGS 0 ST,
1 REGS 1 ST, HERE 5 - 0 LD, 2 REGS 0 ST, 4 CLC, 102044 ,
ELSE PUP JSB, THEN JMP,
BASE !
;S

BLOCK 289 (441B)
OK
```

APPENDIX B - PROGRAM LISTINGS

This is a listing of the actual FORTRAN program codes used in implementing the tape reading and data analysis operations

```
              PROGRAM  NOISE
C
C      THIS PROGRAM WAS WRITTEN BY DR  STEN ODENWALD FOR
C      THE GWEN PROGRAM AT NRL ON MAY 9, 1983
C
C      FUNCTION: TO READ A 9-TRACK TAPE AND EXAMINE THE
C      NOISE STATISTICS OF THE VLF RADIO BACKGROUND
C
C      THIS PROGRAM IS SPECIFICALLY DESIGNED TO HANDLE THE
C      TAPES RECORDED AFTER MAY 31, 1983 WHICH CONTAINED
C      DATA GROUPS CONSISTING OF 10 CONSECUTIVE DATA RECORDS
C      THE PROGRAM CALCULATES AVERAGED QUANTITIES FOR EACH GROUP
C      AND CAN BE MODIFIED TO HANDLE THE DATA BETWEEN MAY 20 AND
C      MAY 31.
C
C
      COMMON/HEADER/ IDREC(30),IST(4),STSC,SPSC
      COMMON/DATA/ IDATA(2,10000),NCH
      COMMON/AUTO/ TPD(2,3,5000)
      COMMON/TIME/ IH,IM,SEC,ATIM(5000)
      CHARACTER*30 FILENAM
      CHARACTER BUFFER*32768
      BYTE JDATA(32768),TEST(100)
      EQUIVALENCE (JDATA,BUFFER)
      DIMENSION FMAX(2,2000)
      DIMENSION TPDI(3),X(5000),PERCENT(2,5000),SIGMA(2,2000)
      DIMENSION AVE(2,2000),FTIM(5000),FDATA(2,5000),TIM(2000)
      LOGICAL ERRFLG
C
C      OPEN THE TAPE FILE ON THE SCRATCH DISC CONTAINING
C      THE DATA FROM THE GWEN OBSERVING RUN
C
      TYPE*,'INPUT TAPE FILE NAME'
C     READ(5,333) FILENAM
C     FILENAM='SIA1.[ODENWALD]B.DAT'
333   FORMAT(5X,A30)
      OPEN(UNIT=1,CARRIAGECONTROL='LIST',
     1STATUS='UNKNOWN',RECORDSIZE=20040)
C
C      IDATA CONTAINS THE INTEGER VALUES FOR UP TO
C      10,000 DATA SAMPLES FOR TWO CHANNELS EACH
C      HAVING N1 AND N2 SAMPLES RESPECTIVELY.
C
C      ITPD IS THE VECTOR CONTAINING THE THREE
C      THRESHOLD SENSITIVITY LEVELS FOR THE TPD
C
C
C      PROGRAM BEGINS
C
C      DEFINE NUMBER OF WORDS IN DATA RECORD
C                                 ID RECORD
      NDA = 10000
      NID = 20
      NTOT=NDA+NID
      NBY = 2*NTOT
```

```
C
C       NUMBER OF TAPE RECORDS
C
        MREC = 150
        NSKIP = 0
        DO 88 I=1,30
        IDREC(I)=0
88      CONTINUE
C
C       calibration constant for gain 1 to convert
C       from data units (volts) squared to watts/meter square
C
        pcal=8.62e-19
C
C       INITIALIZE PLOT SCALES
C
        XS1 = .002
        YS1 = 1.0E-6
C       LOG-LOG PLOT
        XS2 = 3.33
        YS2 = 1.33
C       AVERAGES AND SIGMA
        XS3 = .005
        YS4 = 2.0E-12
        YS5 = .005
        YS3 = .002
C       TYPE*,'TAPE NUMBER'
C       READ*,IDREC(30)
C       TYPE*,'NUMBER OF RECORDS TO SKIP'
C       READ*,NSKIP
C       type*,'NUMBER OF RECORDS TO PROCESS'
C       read*,mrec
C       TYPE*,'SKIP = ',NSKIP,' PROCESS = ',MREC
        IDREC(30)=1
C
C       INITIALIZE PLOT UTILITY
        CALL PLOTST(5,'IN',0)
C
C       INITIALIZE DATA ARRAYS
C
        DO 35 I=1,2
        DO 40 J=1,100
        PERCENT(I,J)=0.
        DO 41 K=1,3
        TPD(I,K,J)=0.
41      CONTINUE
40      CONTINUE
35      CONTINUE
        DO 76 I=1,100
        TEST(I) = 0
76      CONTINUE
C
C       READ TAPE RECORD OF LENGTH NBY BYTES
C
        ISTT=1
        IPAR = 0
        NCH = 2
        IPLOT=1
        NNREC=NSKIP
        NREC = 0
        IF(NSKIP.EQ.0) GO TO 100
        DO 201 II=1,NSKIP
```

```
      READ(1,5) BUFFER
5     FORMAT(A)
201   CONTINUE
      MXREC=MREC+NSKIP
      WRITE(6,555)
555   FORMAT(' TAPE RECORDS SKIPPED')
111   FORMAT(1HO,6X,'TIME',6X,' RECORD',8X, CHANNEL',6X,
     1 'AVERAGE',6X,'V-SUB-D/20DB',10X,'PEAK/M SQ'///)
      IFIRST = 1
      jgain = 0
100   NREC=NREC+1
      IF(NREC GT MREC) GO TO 1005
      READ(1,5,END=1004) BUFFER
C     WRITE(6,888) (JDATA(I),I=1,10)
C888  FORMAT(10I5)
C
C     NOW TEST THE FIRST 100 BYTES TO MAKE CERTAIN
C     THAT THE CURRENT RECORD AND THE PREVIOUS
C     RECORDS ARE NOT IDENTICAL. IF THE MULTIPLEXER
C     HANGS UP THIS WILL BE THE CASE
C
      IF(IFIRST.EQ.0) GO TO 889
C     THIS IS THE FIRST RECORD FROM THE TAPE
      DO 87 IM=1,100
      TEST(I)=JDATA(I)
87    CONTINUE
      IFIRST = 0
      GO TO 887
889   DO 86 I=1,100
      IF(TEST(I).NE.JDATA(I)) GO TO 887
86    CONTINUE
C     IF ALL ELEMENTS NOT IDENTICAL THIS IS GOOD DATA
      WRITE(6,886) NREC
886   FORMAT(' DETECTED REPEATED RECORD ',I4,' RECORD SKIPPED')
      NREC=NREC-1
      GO TO 100
887   CALL DECODE(JDATA,NBY,NREC,ISTT)
C
C     see if the gain setting has changed
C
      IF(JGAIN.EQ.IDREC(16)) GO TO 937
      WRITE(6,938) IDREC(16)
938   FORMAT(' THE GAIN IS NOW SET TO  ',I5)
      JGAIN=IDREC(16)
C
C     COMPUTE AVERAGE VALUE AND SIGMA OF
C     DATA IN RECORD
C
C     PLOT THE FIRST RECORD IN CHANNEL 1 AND 2
C     IF THIS IS THE FIRST RECORD PROCESSED
C     EXPRESS X AXIS AS TIME IN MILLI SECONDS
C
937   IF(IPLOT.NE.1) GO TO 50
      DELT=1000./6200.
      SUM1=0
      SUM2=0.
      KK=1
      DO 32 I=1,5000
      FTIM(I)=I*DELT
      fdata(1,i)=(1.0*idata(1,i)/16.)**2
      fdata(2,i)=(1.0*IDATA(2,I)/16.)**2.
```

```
         SUM1=SUM1+FDATA(1,I)
         SUM2=SUM2+FDATA(2,I)
12       CONTINUE
         AVEKK=SUM1/5000.
         AVELL=SUM2/5000.
         XST=10./(5000 *DELT)
         YS1= 2/AVEKK
         YSO =  2/AVELL
         WRITE(6,89) (IDREC(KKK),KKK=1,20)
89       FORMAT(' TAPE ID    ',10I10/)
         IF(NREC.EQ.1) WRITE(6,111)
C
C        determine the y axis limit IN UNITS OF
C        10(-15) WATTS/METER SQUARE/HZ
C
C        one channel is at a gain of 1 while the
C        second channel is 30db lower in gain (factor of 33)
C
         SCALE=YS1
         IF(FDATA(1,10).LT FDATA(2,10)) SCALE=YSO
         BBB=8.*pcal*1.0e15*(10**(30./20.))/SCALE
         AAA=8.*pcal*1.0e15/SCALE
         c1 = aaa
         c2 = bbb
         if(fdata(2,1).gt.fdata(1,1)) c1 = bbb
         if(fdata(2,1).gt fdata(1,1)) c2 = aaa
         C1=C1/3100.
         C2=C2/3100.
         CALL PLOT(.5,2.,-3)
         CALL PLOTT(FTIM,FDATA,3,XST,SCALE,5000,1,c1,c2)
         IPLOT=0
50       DO 150 J=1,2
         CALL STAT(J,SIG,AV,AAV,10000,NREC,FAX)
         SIGMA(J,NREC)=AAV
         AVE(J,NREC)=AV
         FMAX(J,NREC)=FAX
         FDATA(2,NREC)=(1.0*IDATA(2,1000))**2.
150      CONTINUE
         GO TO 100
200      WRITE(6,2)
2        FORMAT(' ERROR IN INITIALIZING TAPE')
         GO TO 1000
201      WRITE(6,3)
3        FORMAT(' END OF TAPE ASSUMED')
         GO TO 1005
1004     WRITE(6,1006) NREC
1006     FORMAT(' END OF DISK OR TAPE FILE DETECTED
      1 AFTER RECORD NUMBER    ',I5)
1005     NREC = NREC-1
C
C        NOW COMPUTE AVERAGES FOR EACH GROUP OF TEN
C        RECORDS
C
         SMT1=0.
         SMT2=0.
         DO 412 K=1,2
         J=1
         AT=ATIM(1)
         SUM1=0.
         SUM2=0.
         SMX= 0
```

```
      DO 411 I=1,NREC
      IF(ABS(ATIM(I)-AT) GT  01) GO TO 413
      SUM1=SUM1+AVE(K,I)
      SUM2=SUM2+SIGMA(K,I)
      IF(FMAX(K,I) GT SMAX)SMX = FMAX(K,I)
      IF(I EQ NREC) GO TO 413
      GO TO 411
413   AVE(K,J)=SUM1/10
      SIGMA1=SUM2/10.
      SIGMA(K,J)=20*ALOG10(AVE(K,J)/SIGMA1)
      FMAX(K,J)=SMX
      FDATA(1,J)=ATIM(I-1)
      FDATA(2,J)=FDATA(2,I-1)
      AT=ATIM(I)
      SUM1=AVE(K,I)
      SUM2=SIGMA(K,I)
      SMX = FMAX(K,I)
      IF(K.EQ 1) SMT1 = SMT1+AVE(1,J)
      IF(K.EQ.2) SMT2 = SMT2 +AVE(2,J)
      J=J+1
411   CONTINUE
      J=J-1
      SMT1 = SMT1/J
      SMT2=SMT2/J
C     AVE(K,J)=SUM1/10.
C     SIGMA(K,J)=20.*ALOG10(AVE(K,J)/SIGMA1)
C     FMAX(K,J)=SMX
C     FDATA(1,J)=AT
412   CONTINUE
      WRITE(7,434) IDREC(5),IDREC(4),IDREC(3),IST(1),IST(2)
434   FORMAT(' ',5I4)
      DO 415 I=1,J
C     TYPE*,I,FMAX(1,I),FMAX(2,I),SIGMA(1,I),SIGMA(2,I)
      WRITE(7,435) I,FDATA(1,I),AVE(1,I),AVE(2,I)
435   FORMAT(' ',I4,3F15.2)
      ATIM(I)=FDATA(1,I)
415   CONTINUE
      XS3 = 10./30.
C
C     COMPUTE Y AXIS SCALES AND LIMITS
C
C     YS1 = 1./SMT1
C     IF(AVE(1,10) LT AVE(2,10)) YS1 = 1./SMT2
C     BBB=8.*3.08E-9/YS1
C     AAA=8.*2.02E-4/YS1
C     TYPE*,YS1,BBB,AAA
C     C1 = BBB
C     C2 = AAA
C     IF(AVE(1,10).LT.AVE(2,10)) C2 = BBB
C     IF(AVE(1,10).LT.AVE(2,10)) C1 = AAA
      CALL PLOT(11.,0.,-3)
      CALL PLOTT(ATIM,AVE,5,XS3,YS1,J,J,c1,c2)
C
C     PLOT THE V SUB D FOR EACH RECORD
C
      YS5 = 4.0/100
      CALL PLOT(11.0,0.,-3)
      CALL PLOTT(ATIM,SIGMA,4,XS3,YS5,J,J,100.,100 )
C
C     PLOT THE PEAK POWER IN EACH RECORD / MEAN POWER
C
```

```
      CALL PLOT(11 .0 ,-3)
      SCALE=4 /1 0E11
      AAA=862.
      BBB=862 *10**(30 /20 )
      C2=AAA
      C1=BBB
      IF(FMAX(1,1) GT FMAX(2,1)) C1=AAA
      IF(FMAX(1,1) GT FMAX(2,1)) C2=BBB
      CALL PLOTT(ATIM,FMAX,6,XS3,SCALE,J,J,c1,c2)
C
C     NOW PLOT TAPE ID PARAMETERS ON PLOT HEADER
C
      IDREC(29)=NREC
      IDREC(28) = IPAR
      IDREC(27) = 1
      CALL PLOT(9 5,0 ,-3)
      CALL HEADER(NID)
1000  CALL PLOTND
      CLOSE(UNIT=1)
      STOP
      END
```

```
              PROGRAM  PEAKS
C
C       THIS PROGRAM WAS WRITTEN BY DR  STEN ODENWALD FOR
C       THE GWEN PROGRAM AT NRL ON JUNE 7, 1983
C       ITS FUNCTION IS TO PLOT THE HIGHEST RECORDED NOISE
C       PEAK FOUND IN A GROUP OF 10 CONSECUTIVE DATA RECORDS
C
C
C
        COMMON/HEADER/ IDREC(30), IST(4), STSC, SPSC
        COMMON/DATA/ IDATA(2, 10000), NCH
        COMMON/AUTO/ TPD(2, 3, 5000)
        COMMON/TIME/ IH, IM, SEC, ATIM(5000)
        CHARACTER*30 FILENAM
        CHARACTER BUFFER*32768
        BYTE JDATA(32768), TEST(100)
        EQUIVALENCE (JDATA, BUFFER)
        DIMENSION FMAX(2, 2000)
        DIMENSION TPDI(3), X(5000), PERCENT(2, 5000), SIGMA(2, 2000)
        DIMENSION AVE(2, 2000), FTIM(5000), FDATA(2, 5000), TIM(2000)
        LOGICAL ERRFLG
C
C       OPEN THE TAPE FILE ON THE SCRATCH DISC CONTAINING
C       THE DATA FROM THE GWEN OBSERVING RUN
C
C       TYPE*, 'INPUT TAPE FILE NAME'
C       READ(5, 333) FILENAM
C       FILENAM='SIA1. [ODENWALD]B. DAT'
333     FORMAT(5X, A30)
        OPEN(UNIT=1, CARRIAGECONTROL='LIST',
     1STATUS='UNKNOWN', RECORDSIZE=20040)
C
C       IDATA CONTAINS THE INTEGER VALUES FOR UP TO
C       10,000 DATA SAMPLES FOR TWO CHANNELS EACH
C       HAVING N1 AND N2 SAMPLES RESPECTIVELY
C
C       ITPD IS THE VECTOR CONTAINING THE THREE
C       THRESHOLD SENSITIVITY LEVELS FOR THE TPD
C
C
C       PROGRAM BEGINS
C
C       DEFINE NUMBER OF WORDS IN DATA RECORD
C                                    ID RECORD
        NDA = 10000
        NID = 20
        NTOT=NDA+NID
        NBY = 2*NTOT
C
C       NUMBER OF TAPE RECORDS
C
        type*, 'type number of records to read'
        read*, mrec
C       MREC=1100
        NSKIP = 0
        DO 88 I=1, 30
        IDREC(I)=0
88      CONTINUE
C
c       calibration constant for gain 1 to convert
c       from data units (volts) squared to watts/meter square
```

```
      pcal=8.62e-19
C
      TYPE*, 'TAPE NUMBER'
      READ*, IDREC(30)
      TYPE*, 'NUMBER OF RECORDS TO SKIP'
      READ*, NSKIP
      type*, 'NUMBER OF RECORDS TO  (OCESS'
      read*, mrec
      TYPE*, 'SKIP = ', NSKIP, ' PROCESS = ', MREC
      IDREC(30)=1
C
C     INITIALIZE PLOT UTILITY
      CALL PLOTST(5, 'IN', 0)
C
C     INITIALIZE DATA ARRAYS
C
      DO 35 I=1, 2
      DO 40 J=1, 100
      PERCENT(I, J)=0.
      DO 41 K=1, 3
      TPD(I, K, J)=0.
41    CONTINUE
40    CONTINUE
35    CONTINUE
      DO 76 I=1, 100
      TEST(I) = 0
76    CONTINUE
C
C     READ TAPE RECORD OF LENGTH NBY BYTES
C
      ISTT=1
      IPAR = 0
      NCH = 2
      IPLOT=1
      NNREC=NSKIP
      NREC = 0
      IF(NSKIP.EQ.0) GO TO 100
      DO 201 II=1, NSKIP
      READ(1, 5) BUFFER
5     FORMAT(A)
201   CONTINUE
      MXREC=MREC+NSKIP
      WRITE(6, 555)
555   FORMAT(' TAPE RECORDS SKIPPED')
111   FORMAT(1H0, 6X, 'TIME', 6X, ' RECORD', 8X, 'CHANNEL', 6X,
     1'AVERAGE', 6X, 'V-SUB-D/20DB', 10X, 'PEAK POWER'///)
      IFIRST = 1
      jgain = 0
100   NREC=NREC+1
      IF(NREC.GT.MREC) GO TO 1005
      READ(1, 5, END=1004) BUFFER
C     WRITE(6, 888) (JDATA(I), I=1, 10)
C888  FORMAT(10I5)
C
C     NOW TEST THE FIRST 100 BYTES TO MAKE CERTAIN
C     THAT THE CURRENT RECORD AND THE PREVIOUS
C     RECORDS ARE NOT IDENTICAL.  IF THE MULTIPLEXER
C     HANGS UP THIS WILL BE THE CASE
C
      IF(IFIRST.EQ.0) GO TO 889
```

```
C       THIS IS THE FIRST RECORD FROM THE TAPE
        DO 87 IM=1,100
        TEST(I)=JDATA(I)
87      CONTINUE
        IFIRST = 0
        GO TO 887
889     DO 86 I=1,100
        IF(TEST(I).NE.JDATA(I)) GO TO 887
86      CONTINUE
C       IF ALL ELEMENTS NOT IDENTICAL THIS IS GOOD DATA
        WRITE(6,886) NREC
886     FORMAT(' DETECTED REPEATED RECORD ',I4,' RECORD SKIPPED')
        NREC=NREC-1
        GO TO 100
887     CALL DECODE(JDATA,NBY,NREC,ISTT)
C
C       see if the gain setting has changed
C
        IF(JGAIN.EQ.IDREC(16)) GO TO 937
        WRITE(6,938) IDREC(16)
938     FORMAT(' THE GAIN IS NOW SET TO  ',I5)
        JGAIN=IDREC(16)
C
C       COMPUTE AVERAGE VALUE AND SIGMA OF
C       DATA IN RECORD
C
C       PLOT THE FIRST RECORD IN CHANNEL 1 AND 2
C       IF THIS IS THE FIRST RECORD PROCESSED
C       EXPRESS X AXIS AS TIME IN MILLI SECONDS
C
937     IF(IPLOT.NE.1) GO TO 50
        DELT=1000./6200.
        SUM1=0.
        SUM2=0.
        KK=1
        DO 32 I=1,5000
        FTIM(I)=I*DELT
        fdata(1,i)=(1.0*idata(1,i)/16.)**2.
        fdata(2,i)=(1.0*IDATA(2,I)/16.)**2.
        SUM1=SUM1+FDATA(1,I)
        SUM2=SUM2+FDATA(2,I)
32      CONTINUE
        AVEKK=SUM1/5000.
        AVELL=SUM2/5000.
        XST=10./(5000.*DELT)
        YS1=.2/AVEKK
        YSO = .2/AVELL
        WRITE(6,89) (IDREC(KKK),KKK=1,20)
89      FORMAT(' TAPE ID  ' ,10I10/)
        IF(NREC.EQ.1) WRITE(6,111)
C
C       determine the y axis limit IN UNITS OF
C       10(-10) WATTS/METER SQUARE/HERTZ
C
C       one channel is at a gain of 1 while the
C       second channel is 30db lower in gain (factor of 33)
C
        SCALE=YS1
        IF(FDATA(1,10).LT.FDATA(2,10)) SCALE=YSO
        BBB=8.*pcal*1.0e15*(10**(30./20.))/SCALE
        AAA=8.*pcal*1.0e15/SCALE
```

```
      c1 = aaa/3100.
      c2 = bbb/3100
      if(fdata(2,1) gt fdata(1,1)) c1 = bbb
      if(fdata(2,1) gt fdata(1,1)) c2 = aaa
      CALL PLOT( 5,2.,-3)
      CALL PLOTT(FTIM,FDATA,3,XST,SCALE,5000,1,c1,c2)
      IPLOT=0
50    DO 150 J=1,2
      CALL STAT(J,SIG,AV,AAV,10000,NREC,FAX)
      FMAX(J,NREC)=FAX
      FDATA(2,NREC)=(1.0*IDATA(2,1000))**2
150   CONTINUE
      GO TO 100
900   WRITE(6,2)
2     FORMAT(' ERROR IN INITIALIZING TAPE')
      GO TO 1000
901   WRITE(6,3)
3     FORMAT(' END OF TAPE ASSUMED')
      GO TO 1005
1004  WRITE(6,1006) NREC
1006  FORMAT(' END OF DISK OR TAPE FILE DETECTED
     1 AFTER RECORD NUMBER    ',I5)
1005  NREC = NREC-1
C
C     NOW COMPUTE AVERAGES FOR EACH GROUP OF TEN
C     RECORDS
C
      YMAX1=0.
      YMAX2=0.
      DO 412 K=1,2
      J=1
      AT=ATIM(1)
      SMX= 0.
      DO 411 I=1,NREC
      IF(ABS(ATIM(I)-AT).GT..01) GO TO 413
      IF(FMAX(K,I).GT.SMAX)SMX = FMAX(K,I)
      IF(FMAX(1,I).GT.YMAX1) YMAX1=FMAX(1,I)
      IF(FMAX(2,I).GT.YMAX2) YMAX2=FMAX(2,I)
      IF(I.EQ.NREC) GO TO 413
      GO TO 411
413   FMAX(K,J)=SMX
      FDATA(1,J)=ATIM(I-1)
      FDATA(2,J)=FDATA(2,I-1)
      AT=ATIM(I)
      SMX = FMAX(K,I)
      J=J+1
411   CONTINUE
      J=J-1
C     AVE(K,J)=SUM1/10.
C     SIGMA(K,J)=20.*ALOG10(AVE(K,J)/SIGMA1)
C     FMAX(K,J)=SMX
C     FDATA(1,J)=AT
412   CONTINUE
      WRITE(7,434) IDREC(5),IDREC(4),IDREC(3),IST(1),IST(2)
434   FORMAT(' ',5I4)
      DO 415 I=1,J
C     TYPE*,I,FMAX(1,I),FMAX(2,I),SIGMA(1,I),SIGMA(2,I)
      WRITE(7,435) I,FDATA(1,I),FMAX(1,I),FMAX(2,I)
435   FORMAT(' ',I4,3F15.2)
      ATIM(I)=FDATA(1,I)
415   CONTINUE
```

```
C     XS3 = 10./30.
      XS3=10./80.
C
C     COMPUTE Y AXIS SCALES AND LIMITS
C
      YS1 = 1./SMT1
      IF(AVE(1,10).LT.AVE(2,10)) YS1 = 1./SMT2
C     BBB=8.*3.08E-9/YS1
C     AAA=8.*2.02E-4/YS1
C     TYPE*,YS1,BBB,AAA
C     C1 = BBB
C     C2 = AAA
C     IF(AVE(1,10).LT.AVE(2,10)) C2 = BBB
C     IF(AVE(1,10).LT.AVE(2,10)) C1 = AAA
      CALL PLOT(11.,0.,-3)
      SCALE=4./2.5e8
      C1=8.62E-9*4./SCALE
      C2=8.62E-9*10**(30./20.)*4./SCALE
      IF(YMAX2.GT.YMAX1) C1=8.62E-9*4./SCALE
      IF(YMAX2.GT.YMAX1) C2=8.62E-9*10**(1.5)*4./SCALE
      CALL PLOTT(ATIM,FMAX,6,XS3,SCALE,J,J,c1,c2)
C
C     NOW PLOT TAPE ID PARAMETERS ON PLOT HEADER
C
      IDREC(29)=NREC
      IDREC(28) = IPAR
      IDREC(27) = 1
      CALL PLOT(9.5,0.,-3)
      CALL HEADER(NID)
1000  CALL PLOTND
      CLOSE(UNIT=1)
      STOP
      END
```

```
      SUBROUTINE PLOTT(X,Y,INDX,XSCALE,YSCALE,NDAT,NREC,ch1,ch2)
C
C     THIS IS THE SUBROUTINE PACKAGE WHICH GENERATES PLOTS OF THE
C     INDX = 1   AMPLITUDE PROBABILITY DISTRIBUTION
C     INDX = 2   TIME PROBABILITY DISTRIBUTION
C     INDX = 3   PLOTS  AMPLITUDE FOR NDAT DATA SAMPLES
C     INDX = 4   PLOTS SIGMA VS RECORD NUMBER
C     INDX = 5   PLOTS AVERAGE AMPLITUDE VS RECORD NUMBER
C     INDX = 6   PLOTS MAXIMUM DEVIATION VS RECORD NUMBER
C
C     WRITTEN BY DR  STEN ODENWALD
C                NAVAL RESEARCH LABORATORY
C                CODE 4138-0
C                WASHINGTON, D C   20375
C
C
C
      CHARACTER*10 XTIT,YTIT,XTIT1,YTIT12,YTIT3
      CHARACTER*10 YTIT4,YTIT5,XTIT2,YTIT6,XTIT99
      CHARACTER*1 VAR
      CHARACTER*30 XTIT34
      CHARACTER*12 TITLE1,TITLE2
      COMMON/HEADER/IDREC(30),IST(4),ST,SP
      COMMON/TIME/IH,IM,SEC,ATIM(5000)
      common/auto/tp(2,3,5000)
      DIMENSION X(5000),Y(2,5000)
      REAL*4 FII
      INR=1
3333  CALL PLOT(8.,0.,2)
      CALL PLOT(8.,10.,2)
      CALL PLOT(0.,10.,2)
      CALL PLOT(0.,0.,2)
      IF(INDX.NE.1)CALL PLOT(4.,0.,2)
      IF(INDX.NE.1)   CALL PLOT(4.,10.,2)
      CALL PLOT(0.,0.,3)
C
C     INITIALIZE TITLES
C
      XTIT1= '  POWER    '
      XTIT2= '  TIME     '
      XTIT34=' '
      YTIT12='  PERCENT '
      YTIT3 ='  POWER    '
      YTIT4 ='    VD     '
      YTIT5 ='           '
      TITLE1='FIRST RECORD'
      TITLE2='ENTIRE  TAPE'
      YTIT6= 'PEAK POWER'
5     IF(INDX.NE.1) GO TO 10
15    XTIT=XTIT1
      YTIT=YTIT12
      GO TO 50
10    IF(INDX.NE.2) GO TO 20
      XTIT=XTIT2
      YTIT=YTIT12
      GO TO 50
20    IF(INDX.NE.3) GO TO 30
      XTIT=XTIT34
      YTIT=YTIT3
      GO TO 50
30    IF(INDX.NE.4) GO TO 40
```

```
      YTIT=YTIT4
      GO TO 50
40    IF(INDX.NE.5) GO TO 45
      XTIT=XTIT34
      YTIT=YTIT3
      GO TO 50
45    IF(INDX.NE.6) GO TO 46
      XTIT=XTIT34
      YTIT=YTIT6
      GO TO 50
46    WRITE(6,1)
1     FORMAT(' NO CODE FOR THIS PLOT, SELECT ONE')
      READ(5,2) INDX
2     FORMAT(I1)
      IF(INDX .EQ. 0) RETURN
      GO TO 5
C
C     NOW DRAW TIC MARKS ON X AXIS AND LABEL
C
50    IF(INDX.EQ.3) GO TO 60
      IF(INDX.EQ.4) GO TO 60
      IF(INDX.EQ.5) GO TO 60
      IF(INDX.EQ.6) GO TO 60
C
C     DRAW LOGARITHMIC INTERVALS
C     ON X AXIS
C
13    DO 100 I=1,3
      DO 101 J=1,9
      FII=J*10**(I-1)
      X1=XSCALE*ALOG10(FII)
      CALL PLOT(8.,X1,3)
      CALL PLOT(7.9,X1,2)
      IF(J.EQ.1) CALL PLOT(7.8,X1,2)
101   CONTINUE
100   CONTINUE
C
C     NOW LABEL DECADES
C
      DO 150 I=2,4
      X2=XSCALE*(I-2)
      IF(INR.EQ.1)CALIB=CH1
      IF(INR.EQ.2) CALIB=CH2
      IF(INDX.EQ.2) CALIB=CH1
      XN=CALIB*10**(I-2)
      CALL NUMBER(8.2,X2,.1,XN,90.,5)
150   CONTINUE
      CALL SYMBOL(9.,3.5,.2,%REF(XTIT),90.,10)
      IF(INDX.NE.3) GO TO 70
C
C     LABEL THE PLOT BY THE RECORD NUMBER RETRIEVED
C
      XTIT='RECORD'
      CALL SYMBOL(9.,3.,.3,%REF(XTIT),90.,6)
      CALL NUMBER(9.,5.5,.3,FLOAT(NREC),90.,1)
      GO TO 70
C
C     DRAW X AXIS FOR LINEAR TIME PLOT
C
60    IF(INDX.NE.3) GO TO 61
      DO 200 I=1,9
```

```
      X1=I*1
      DEC = X(1)*500
      X2 = DEC*X1
      CALL PLOT(8.,X1,3)
      CALL PLOT(7.9,X1,2)
      CALL PLOT(4.,X1,3)
      CALL PLOT(3.9,X1,2)
      CALL NUMBER(8.2,X1-.2,.1,X2,90.,1)
200   CONTINUE
      GO TO 63
61    DEC=30./10
C
C     mark the x axis in hours
C
      DO 202 I=1,9
      X1=I*1
      I2 = IST(1)+DEC*X1
      IF(I2.GT.24) I2=I2-24
      CALL PLOT(8.,X1,3)
      CALL PLOT(7.9,X1,2)
      CALL PLOT(4.,X1,3)
      CALL PLOT(3.9,X1,2)
      CALL NUMBER(8.2,X1-.2,.1,FLOAT(I2),90.,1)
202   CONTINUE
63    XTIT='TIME IN'
      CALL SYMBOL(9.0,3.,.2,%REF(XTIT),90.,7)
      IF(INDX.NE.3) GO TO 201
      XTIT='MILLI SECO'
      CALL SYMBOL(9.0,4.6,.2,%REF(XTIT),90.,10)
      XTIT='NDS'
      CALL SYMBOL(9.0,6.6,.2,%REF(XTIT),90.,3)
201   XTIT='RECORD'
      IF(INDX.NE.3) CALL SYMBOL(-.2,3.,.3,%REF(TITLE2),90.,12)
      IF(INDX.EQ.3)CALL SYMBOL(-.2,3.,.3,%REF(XTIT),90.,6)
      XTIT='HOURS  '
      IF(INDX.NE.3)CALL SYMBOL(9.0,4.6,.2,%REF(XTIT),90.,7)
      IF(INDX.EQ.3)CALL NUMBER(-.2,5.5,.3,FLOAT(NREC),90.,1)
C
C     NOW LABEL Y AXIS
C
70    IF(INDX.EQ.3) GO TO 80
      IF(INDX.EQ.4) GO TO 80
      IF(INDX.EQ.5) GO TO 80
      IF(INDX.EQ.6) GO TO 80
C
C     DRAW LOG TIC MARKS ON Y AXIS
C
      DO 250 I=2,6
      Y2=8.-YSCALE*(I-1)
      YDX=I-5
      IF(INDX.EQ.1) GO TO 259
      IF(I.LT.5)YDX=I-2
259   YN=10**YDX
      CALL NUMBER(Y2,-.5,.1,YN,90.,3)
250   CONTINUE
      DO 300 I=1,6
      YO=8.-YSCALE*(I-1)
      DO 301 J=1,10
      R2=J
      Y1=YO-YSCALE*ALOG10(R2)
```

```
      CALL PLOT(Y1,0.,3)
      CALL PLOT(Y1, 1,2)
301   CONTINUE
300   CONTINUE
      GO TO 90
C
C     DRAW LINEAR Y AXIS SCALE
C
80    FMAX = 4 /yscale
      if(indx eq 3) fmax = ch1
      if(indx eq 5) fmax = ch1
      IF(INDX.EQ.6) FMAX= CH1
      DO 400 I=1,20
      Y1=.4*I
      CALL PLOT(Y1,0.,3)
      CALL PLOT(Y1, 1,2)
400   CONTINUE
C
C     LABEL THE Y AXIS
C
      CALL NUMBER(0.,-.7,.1,FMAX,90.,5)
      CALL NUMBER(3.8,-.7,.1,0.,90.,5)
      IF(INDX.EQ.3) FMAX = ch2
      IF(INDX.EQ.5) FMAX = ch2
      IF(INDX.EQ.6) FMAX=CH2
      CALL NUMBER(4.1,-.7,.1,FMAX,90.,5)
      CALL NUMBER(8.,-.7,.1,0.,90.,5)
C
C     LABEL CHANNELS ON Y AXIS
C
90    CALL SYMBOL(4.5,-1.2,.2,%REF(YTIT),-180.,10)
      ROT=-180.
      S1=4.5
      S2=3.6
      S3=4.3
      S4=3.0
      S5=-.9
      S6=-1.
      IF(INDX.EQ.2) GO TO 920
      IF(INDX.EQ.5) GO TO 910
      IF(INDX.EQ.3) GO TO 910
      IF(INDX.EQ.1) ROT=90.
910   YTIT3='10   WATTS'
      CALL SYMBOL(S1,S5,.1,%REF(YTIT3),ROT,10)
      IF(INDX.EQ.1) CALL SYMBOL(9.2,3.4,.1,%REF(YTIT3),ROT,10)
      YTIT4='/METER'
      CALL SYMBOL(S2,S5,.1,%REF(YTIT4),ROT,6)
      IF(INDX.EQ.1)CALL SYMBOL(9.2,4.4,.1,%REF(YTIT4),ROT,6)
      YTIT='-15'
      IF(INDX.EQ.6) YTIT='-10'
      CALL SYMBOL(S3,S6,.1,%REF(YTIT),ROT,3)
      IF(INDX.EQ.1)CALL SYMBOL(9.1,3.6,.1,%REF(YTIT),ROT,3)
      YTIT='2'
      CALL SYMBOL(S4,S6,.1,%REF(YTIT),ROT,1)
      IF(INDX.EQ.1)CALL SYMBOL(9.1,5.,.1,%REF(YTIT),ROT,1)
      IF(INDX.EQ.1) GO TO 95
920   YTIT='CH1'
      CALL SYMBOL(2.,-1.2,.2,%REF(YTIT),-180.,3)
      YTIT='CH2'
      CALL SYMBOL(6.,-1.2,.2,%REF(YTIT),-180.,3)
C
```

```
C
C       NOW PLOT POINTS
C
        IF(INDX.EQ.3) GO TO 600
        IF(INDX.EQ.4) GO TO 600
        IF(INDX.EQ.5) GO TO 600
        IF(INDX.EQ.6) GO TO 600
C
C       SET UP FOR LOG PLOT
C
C       FIRST CHECK TO SEE IF THE TPD IS TO BE PLOTTED
C
        IF(INDX.NE.2) GO TO 95
        DO 97 I2=1,3
        YO = 4.
        DO 96 I1=1,2
        IF(I1.EQ. 2) YO = 8.
        A=TP(I1,I2,1)
        IF(A.LT..001) A = .001
        XX=0.0
        IF(X(1).GT.0.)XX = XSCALE*(ALOG10(X(1))-1.)
        YY = YO-YSCALE*(3+ALOG10(A))
        CALL PLOT(YY,XX,3)
        DO 98 I=2,NDAT
        A=TP(I1,I2,I)
        IF(A.LT..001)A = .001
        XX=XSCALE*(ALOG10(X(I))-1.)
        YY=YO-YSCALE*(3+ALOG10(A))
        CALL PLOT(YY,XX,2)
        IF(I.EQ.2)CALL SYMBOL(YY,XX,.2,I2,90.,-1)
98      CONTINUE
96      CONTINUE
97      CONTINUE
        GO TO 94
95      COE=ALOG10(X(1))
        XX=XSCALE*(ALOG10(X(1))-COE)
        A=Y(INR,1)
        IF(A.LT..000001) A = .000001
        YY=8.0-YSCALE*(6+ALOG10(A))
        CALL PLOT(YY,XX,3)
        DO 650 I=2,NDAT
        A = Y(INR,I)
        IF(A.LT..000001) A = .000001
        XX=XSCALE*(ALOG10(X(I))-COE)
        YY=8.0-YSCALE*(6+ALOG10(A))
        CALL PLOT(YY,XX,2)
650     CONTINUE
94      CALL PLOT(0.,0.,3)
        IF(INDX.EQ.2) RETURN
        XTIT99='CHANNEL  '
        CALL SYMBOL(-.2,4.,.2,%REF(XTIT99),90.,9)
        CALL NUMBER(-.2,6.,.2,FLOAT(INR),90.,1)
        IF(INR.EQ.1)CALL PLOT(11.,0.,-3)
        IF(INR.EQ.2) RETURN
        INR=INR+1
        GO TO 3333
600     XX=XSCALE*X(1)
        YY=4.-YSCALE*Y(1,1)
        IF(YY.LT.0.) YY = 0.
        call plot(yy,xx,3)
        IF(INDX.EQ.6)CALL PLOT(4.,XX,3)
        CALL PLOT(YY,XX,2)
```

```
      DO 500 I=2,NDAT
      XX=XSCALE*X(I)
      YY=4.-YSCALE*Y(1,I)
      IF(YY.LT.0.) YY = 0
      IF(INDX.EQ.6)CALL PLOT(4.,XX,3)
      CALL PLOT(YY,XX,2)
500   CONTINUE
      XX=XSCALE*X(1)
      YY=8.-YSCALE*Y(2,1)
      IF(YY.LT.4.) YY= 4
      IF(INDX.EQ.6)CALL PLOT(8.,XX,3)
      call plot(yy,xx,3)
      CALL PLOT(YY,XX,2)
      DO 550 I=2,NDAT
      XX=XSCALE*X(I)
      YY=8.-YSCALE*Y(2,I)
      IF(YY.LT.4.) YY = 4
      IF(INDX.EQ.6)CALL PLOT(8.,XX,3)
      CALL PLOT(YY,XX,2)
550   CONTINUE
      CALL PLOT(0.,0.,3)
      RETURN
      END
```

```
      [illegible](J, [illegible], AAV, FDAT, [illegible])
C
C        THIS SUBROUTINE TAKES THE DATA FROM EACH
C        OF TWO DATA CHANNELS AND COMPUTES THE
C        AVERAGE VALUE AND SIGMA FOR A SINGLE DATA
C        RECORD CONSISTING OF 5000 POINTS PER CHANNEL
C
C        WRITTEN BY  DR. STEN ODENWALD
C
C
      COMMON/TIME/ IH, IM, SEC, TIM(5000)
      COMMON/DATA/IDATA(2, 10000), NCH
      common/header/idrec(30), itd(4), sts, sps
      DIMENSION FDAT(2, 10000)
      ICOUNT=0
      SUM=0
      SUM2=0.
c
c     read the gain setting and compensate
c     idrec(16) = 1   means 0 db so gain = 1.
c     idrec(16) = 2   means 24 db so gain = .0631
c     idrec(16) = 4   means 43.5 db so gain = .00668
c     idrec(16) = 8   means 63 db  so gain = .000708
c     if idrec(16) equals anything else, gain = 1.
c
      igain=IDREC(16)
      gain = 1.
      if(igain.eq.2) gain = .0631
      if(igain.eq.4) gain = .00668
      if(igain.eq.8) gain = .000708
C     DO 90 I=1, 5000
C     FDAT(J, I)=((1.0*IDATA(J, I)/(16.))**2.)/GAIN**2
C90   CONTINUE
C
C     COMPUTE MEAN SQUARE VOLTAGE = AVERAGE POWER
C
C     DO 100 I=1, 5000
C     SUM=SUM+FDAT(J, I)
C     SUM2=SUM2+SQRT(FDAT(J, I))
C100   CONTINUE
C     AV=SUM/5000.
C     AAV=SUM2/5000.
C     TYPE*, AV
C
C     COMPUTE SIGMA
C
C     SIGMA=0.
C     DO 200 JJ=1, 5000
C     SIGMA=SIGMA+(AV-FDAT(J, JJ))*(AV-FDAT(J, JJ))
C200  CONTINUE
C     SIG=0.
C     IF(ABS(SIGMA).LT..0001) RETURN
C     SIG=20.*LOG10(SQRT(AV)/AAV)
      FMAX = 0.
      DO 250 JJ=1, 5000
C     FM=FDAT(J, JJ)/av
C     if(idrec(4).ne.6) go to 251
C     if(idrec(5).lt.15) go to 251
      fm=Idata(j, jj)
251   IF(FMAX.LT.FM) GO TO 201
      GO TO 250
201   FMAX = FM
250   CONTINUE
      FMAX=FMAX*FMAX/(256.*GAIN)
      WRITE(6, 10) IH, IM, SEC, NREC, J, AV, SIG, FMAX
10    FORMAT(1H , I2, ' ', I2, ' ', F6.3, I10, 5X, I10,
     15X, E10.2, 5X, F10.2, 5X, 1E10.3)
      RETURN
      END
```

```
      SUBROUTINE AUTO(ITPD,X,TPD,NX,NRC)
C
C     AUTOCORRELATES THE ARRAY ITPD OF LENGTH NRC
C
C     WRITTEN BY   DR  STEN ODENWALD
C
C
      COMMON/DATA/IDATA(2,10000),NCH
      DIMENSION TPD(2,3,5000),X(5000),ITPD(3)
C
C     NORMALIZE THE SIGNAL STRENGTH TO UNITY
C     AMPLITUDE FOR EACH POINT ABOVE THE
C     THRESHOLD ITPD AND COMPUTE AUTOCOR.
C
      A = 5000*(NRC-1)
      B = 5000*NRC
      DO 700 L=1,3
      DO 400 J=1,2
      DO 600 I=1,NX
      TD = 0.
      IMAX = 5000-X(I)+1
      DO 550 K=1,IMAX
      INDX=X(I)+K-1
      IF(IDATA(J,K).LT.ITPD(L)) GO TO 550
      IF(IDATA(J,INDX).LT.ITPD(L)) GO TO 550
      TD = TD+1.
550   CONTINUE
559   TPD(J,L,I) = (TPD(J,L,I)*A+TD)/B
600   CONTINUE
400   CONTINUE
700   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DECODE(IARRAY,NBYTE,NREC,IST)
C
C     THIS PROGRAM UNPACKS THE DATA VALUE FROM
C     THE 2-BYTE WORD REPRESENTATION AND STORES
C     THE RESULT IN 'ARRAY'
C
C     WRITTEN BY   DR. STEN ODENWALD
C
C
C
      COMMON/TIME/ IH,IM,SEC,TIM(5000)
      COMMON/HEADER/IDREC(30),ITD(4),STS,SPS
      COMMON/DATA/IDATA(2,10000)
      INTEGER*2 IARRAY(10050)
      INTEG=NBYTE/2
C
C     SWAP THE BYTES
C
      CALL BYSWAP(IARRAY,INTEG)
      II=0
      DO 100 I=1,10000,2
      II=II+1
      IDATA(1,II)=IARRAY(I)
100   CONTINUE
      II=1
      DO 150 I=2,10000,2
      IDATA(2,II)=IARRAY(I)
      II=II+1
150   CONTINUE
      K=1
      DO 200 I=10001,INTEG
      IDREC(K)=IARRAY(I)
      K=K+1
200   CONTINUE
C
C     CALCULATE  TIMES
C
C
C
      A=IDREC(1)*.1
      IF(IDREC(1).LT.0) A=3276.8+(32768+IDREC(1))*.1
      B=2.*IDREC(2)*3276.8
      TS=(A)+IDREC(8)+IDREC(7)*60.+IDREC(6)*3600.+B
      IH=TS/3600
      FH=TS/3600.
      IM=60*(FH-IH)
      FM=60.*(FH-IH)
      SEC=60.*(FM-IM)
      IF(IST.NE.1) GO TO 120
      ITD(1)=IH
      ITD(2)=IM
      STS=SEC
      IST=0
120   ITD(3)=IH
      ITD(4)=IM
      SPS=SEC
C
C     TIME IN HOURS SINCE THE START OF THE TAPE IN MIN PAST
C     START HOUR
C
      TIM(NREC)=(IH-ITD(1))+(IM+(SEC/60.))/60.
      RETURN
      END
```

```
      SUBROUTINE HEADER(N)
C
C     PRINTS A HEADER AT END OF PLOT
C
C     WRITTEN BY  DR. STEN ODENWALD
C
C
      COMMON/HEADER/IDREC(30),IST(4),STSC,SPSC
      CHARACTER*40 XTIT(30),IMO(12),COL
      XTIT(1)='SUMMARY OF GWEN DATA TAPE'
      xtit(2)='FOR'
      xtit(3)='TAPE NUMBER'
      xtit(4)='MONITORING FREQUENCY'
      xtit(5)='CHANNEL 1'
      xtit(6)='CHANNEL 2'
      xtit(7)='BANDWIDTH'
      xtit(8)='HZ'
      xtit(9)='LOCATION'
      xtit(10)='MARYLAND POINT'
      xtit(11)='START TIME'
      xtit(12)='STOP TIME'
      xtit(13)='NUMBER OF RECORDS'
      xtit(14)='                '
      xtit(15)='     '
      xtit(16)='SAMPLE DURATION'
      xtit(17)='INTERVAL BETWEEN SAMPLES'
      XTIT(18)='SEC'
      imo(1)=' JANUARY  '
      imo(2)=' FEBRUARY '
      imo(3)='  MARCH   '
      imo(4)='  APRIL   '
      imo(5)='   MAY    '
      imo(6)='  JUNE    '
      imo(7)='  JULY    '
      imo(8)=' AUGUST   '
      imo(9)=' SEPTEMBER'
      imo(10)=' OCTOBER  '
      imo(11)=' NOVEMBER '
      imo(12)=' DECEMBER '
      col=': '
      call plot(1.0,0.,-3)
      call plot(9.,0.,2)
      call plot(9.,10.,2)
      call plot(0.,10.,2)
      call plot(0.,0.,2)
      call symbol(1.,1.,.3,%ref(xtit(1)),90.,25)
      call symbol(2.,2.5,.2,%ref(xtit(2)),90.,3)
      call number(2.,4.,.2,float(idrec(5)),90.,1)
      call symbol(2.,5.2,.2,%ref(imo(idrec(4))),90.,10)
      call number(2.,7.5,.2,float(idrec(3)),90.,1)
      call symbol(3.,1.5,.3,%ref(xtit(3)),90.,11)
      call number(3.,7.,.5,float(idrec(30)),90.,1)
      call symbol(4.,1.5,.2,%ref(xtit(4)),90.,21)
      ID9=IDREC(9)/100
      call number(4.,6.,.3,float(id9),90.,1)
      call symbol(4.,8.5,.2,%ref('KHZ'),90.,3)
      call symbol(4.5,1.5,.2,%ref(xtit(7)),90.,9)
      call number(4.5,6.,.3,float(idrec(10)),90.,1)
      CALL SYMBOL(4.5,8.5,.2,%REF(XTIT(8)),90.,2)
      call symbol(5.,1.5,.2,%ref(xtit(9)),90.,8)
      call symbol(5.,4.,.3,%ref(xtit(10)),90.,14)
```

```
      call symbol(6.,1.5,.2,%ref(xtit(11)),90.,10)
      IF(IST(1).GT.24) IST(1) = IST(1)-24
      CALL NUMBER(6.,4.,.2,FLOAT(IST(1)),90.,0)
      CALL SYMBOL(6.,5.,.2,%REF(COL),90.,1)
      CALL NUMBER(6.,6.,.2,FLOAT(IST(2)),90.,0)
      CALL SYMBOL(6.,7.,.2,%REF(COL),90.,1)
      CALL NUMBER(6.,8.,.2,STSC,90.,0)
      call symbol(6.5,1.5,.2,%ref(xtit(12)),90.,10)
      IF(IST(3).GT.24) IST(3)=IST(3)-24
      CALL NUMBER(6.5,4.,.2,FLOAT(IST(3)),90.,0)
      CALL SYMBOL(6.5,5.,.2,%REF(COL),90.,1)
      CALL NUMBER(6.5,6.,.2,FLOAT(IST(4)),90.,0)
      CALL SYMBOL(6.5,7.,.2,%REF(COL),90.,1)
      CALL NUMBER(6.5,8.,.2,SPSC,90.,0)
      call symbol(7.0,1.5,.2,%ref(xtit(13)),90.,17)
      call number(7.0,7.0,.2,float(idrec(29)),90.,1)
      call symbol(7.5,1.5,.2,%ref(xtit(14)),90.,13)
      if(idrec(28).ne.0) go to 10
      call symbol(7.5,7.5,.3,%ref(xtit(15)),90.,4)
      go to 20
10    call number(7.5,7.5,.2,float(idrec(28)),90.,1)
20    call symbol(8.0,1.5,.2,%ref(xtit(16)),90.,15)
      F=5000./(6200.)
      call number(8.0,7.5,.2,F,90.,3)
      CALL SYMBOL(8.0,9.,.2,%REF(XTIT(18)),90.,3)
      call symbol(8.5,1.5,.2,%ref(xtit(17)),90.,24)
      F=IDREC(13)*.1
      call number(8.5,7.5,.2,F,90.,1)
      CALL SYMBOL(8.5,9.,.2,%REF(XTIT(18)),90.,3)
      return
      end
```

```
      SUBROUTINE STAT(J,SIG,AV,AAV,NDAT,NREC,FMAX)
C
C     THIS SUBROUTINE TAKES THE DATA FROM EACH
C     OF TWO DATA CHANNELS AND COMPUTES THE
C     AVERAGE VALUE AND SIGMA FOR A SINGLE DATA
C     RECORD CONSISTING OF 5000 POINTS PER CHANNEL
C
C     WRITTEN BY  DR  STEN ODENWALD
C
C
      COMMON/TIME/ IH,IM,SEC,TIM(5000)
      COMMON/DATA/IDATA(2,10000),NCH
      common/header/idrec(30),itd(4),sts,sps
      DIMENSION FDAT(2,10000)
      ICOUNT=0
      SUM=0
      SUM2=0.
c
c     read the gain setting and compensate
c     idrec(16) = 1   means 0 db so gain = 1.
c     idrec(16) = 2   means 24 db so gain = .0631
c     idrec(16) = 4   means 43.5 db so gain = .00668
c     idrec(16) = 8   means 63 db  so gain = .000708
c     if idrec(16) equals anything else, gain = 1.
c
      igain=IDREC(16)
      gain = 1.
      if(igain.eq.2) gain = .0631
      if(igain.eq.4) gain = .00668
      if(igain.eq.8) gain = .000708
      DO 90 I=1,5000
      FDAT(J,I)=((1.0*IDATA(J,I)/(16.))**2.)/GAIN
90    CONTINUE
C
C     COMPUTE MEAN SQUARE VOLTAGE = AVERAGE POWER
C
      DO 100 I=1,5000
      SUM=SUM+FDAT(J,I)
      SUM2=SUM2+SQRT(FDAT(J,I))
100   CONTINUE
      AV=SUM/5000.
      AAV=SUM2/5000.
C     TYPE*,AV
C
C     COMPUTE SIGMA
C
      SIGMA=0.
      DO 200 JJ=1,5000
      SIGMA=SIGMA+(AV-FDAT(J,JJ))*(AV-FDAT(J,JJ))
200   CONTINUE
      SIG=0.
      IF(ABS(SIGMA).LT..0001) RETURN
      SIG=20.*LOG10(SQRT(AV)/AAV)
      FMAX = 0.
      DO 250 JJ=1,5000
      FM=FDAT(J,JJ)/av
      if(idrec(4).ne.6) go to 251
      if(idrec(5).lt.15) go to 251
      fm=fdat(j,jj)
251   IF(FMAX.LT.FM) GO TO 201
      GO TO 250
201   FMAX = FM
250   CONTINUE
      WRITE(6,10) IH,IM,SEC,NREC,J,AV,SIG,FMAX
10    FORMAT(1H ,I2,':',I2,':',F6.3,I10,5X,I10,
     15X,E10.2,5X,F10.2,5X,1E10.3)
      RETURN
      END
```

```
      PROGRAM APD
C
C     THIS PROGRAM WAS WRITTEN BY DR. STEN ODENWALD FOR
C     THE GWEN PROGRAM AT NRL ON MAY 9, 1983.
C
C     FUNCTION: TO READ A 9-TRACK TAPE AND CALCULATE
C     THE AMPLITUDE PROBABILITY DISTRIBUTION FOR USER-SELECTED
C     SAMPLES OF THE DATA
C
C
      COMMON/HEADER/ IDREC(30),IST(4),STSC,SPSC
      COMMON/DATA/ IDATA(2,10000),NCH
      COMMON/AUTO/ TPD(2,3,5000)
      COMMON/TIME/ IH,IM,SEC,ATIM(5000)
      CHARACTER*30 FILENAM
      CHARACTER*14 TITLE
      CHARACTER BUFFER*32768
      BYTE JDATA(32768),TEST(100)
      EQUIVALENCE (JDATA,BUFFER)
      DIMENSION FMAX(2,2000)
      DIMENSION TPDI(3),X(5000),PERCENT(2,5000),SIGMA(2,2000)
      DIMENSION AVE(2,2000),FTIM(5000),FDATA(2,5000),TIM(2000)
      LOGICAL ERRFLG
C
C     OPEN THE TAPE FILE ON THE SCRATCH DISC CONTAINING
C     THE DATA FROM THE GWEN OBSERVING RUN
C
C     TYPE*,'INPUT TAPE FILE NAME'
C     READ(5,333) FILENAM
C     FILENAM='SIA1:[ODENWALD]B.DAT'
333   FORMAT(5X,A30)
      OPEN(UNIT=1,CARRIAGECONTROL='LIST',
     1STATUS='UNKNOWN',RECORDSIZE=20040)
C
C     INITIALIZE PLOT UTILITY
      CALL PLOTST(5,'IN',0)
      IFIRST=1
C
C     IDATA CONTAINS THE INTEGER VALUES FOR UP TO
C     10,000 DATA SAMPLES FOR TWO CHANNELS EACH
C     HAVING N1 AND N2 SAMPLES RESPECTIVELY.
C
C     ITPD IS THE VECTOR CONTAINING THE THREE
C     THRESHOLD SENSITIVITY LEVELS FOR THE TPD
C
C
C     PROGRAM BEGINS
C
C     DEFINE NUMBER OF WORDS IN DATA RECORD
C                                  ID RECORD
      NDA = 10000
      NID = 20
      NTOT=NDA+NID
      NBY = 2*NTOT
C
C     NUMBER OF TAPE RECORDS
C
      MREC = 1120
      NSKIP = 0
      DO 88 I=1,30
      IDREC(I)=0
```

```
.8      CONTINUE
        DO 23 I=1,2
        DO 24 J=1,1000
        PERCENT(I,J)=0
24      CONTINUE
23      CONTINUE
        TYPE*,'TAPE NUMBER'
        READ*,IDREC(30)
100     TYPE*,'WHAT RECORD DO YOU WANT TO APD?'
        READ*,IREC
        IF(IREC.EQ.0) GO TO 1005
        IF(IREC.GT.MREC) GO TO 100
        NSKIP=IREC-1
        MREC=1
        IDREC(30)=1
C
C       READ TAPE RECORD OF LENGTH NBY BYTES
C
        ISTT=1
        IPAR = 0
        NCH = 2
        IPLOT=1
        IF(NSKIP.EQ.0) GO TO 202
        DO 201 II=1,NSKIP
        READ(1,5) BUFFER
5       FORMAT(A)
201     CONTINUE
202     READ(1,5,END=1004) BUFFER
C       WRITE(6,888) (JDATA(I),I=1,10)
C888    FORMAT(10I5)
C
887     CALL DECODE(JDATA,NBY,IREC,ISTT)
C
C       see if the gain setting has changed
C
        GAIN=1.
        JGAIN=IDREC(16)
        IF(JGAIN.EQ.2) GAIN=.0631
        IF(JGAIN.EQ.4) GAIN = .00668
        IF(JGAIN.EQ.8) GAIN = .000708
C
        DELT=1000./6200.
        SUM1=0.
        SUM2=0.
        KK=1
        DO 32 I=1,5000
        FTIM(I)=I*DELT
        fdata(1,i)=(1.0*idata(1,i)/16.)**2.
        fdata(2,i)=(1.0*IDATA(2,I)/16.)**2.
        SUM1=SUM1+FDATA(1,I)
        SUM2=SUM2+FDATA(2,I)
32      CONTINUE
        AVEKK=SUM1/5000.
        AVELL=SUM2/5000.
        XST=10./(5000.*DELT)
        YS1=.1/AVEKK
        YS0 = .1/AVELL
c
c       determine the y axis limit IN UNITS OF
C       10(-15) WATTS/METER SQUARE/HERTZ
c
```

```
      SCALE=YS1
      IF(FDATA(1,10) LT FDATA(2,10)) SCALE=YS0
      BBB=8 *8 62e-4*10**(30 /20 )/(GAIN*SCALE)
      AAA=8 *8 62e-4/(GAIN*SCALE)
      c1 = aaa/3100
      c2 = bbb/3100
      if(fdata(2,1) gt fdata(1,1)) c1 = bbb
      if(fdata(2,1) gt fdata(1,1)) c2 = aaa
      TYPE*, 'LBL1,LBL2',C1,C2
      IF(IDREC(4) NE 6) GO TO 1113
      IF(IDREC(5) LT 15) GO TO 1113
C
C     IF BOTH ARE TRUE. THE GAINS ARE THE SAME FOR
C     EACH PLOT
C
      IF(C1 GT C2) C2=C1
      TYPE*,C1,C2
      IF(C1 LT C2) C1=C2
      TYPE*,C1,C2
1113  IF(IFIRST.EQ.1)CALL PLOT(.5,2.,-3)
      TITLE='ATTENUATION = '
      IF(IFIRST.EQ.0) CALL PLOT(11.,0.,-3)
      CALL SYMBOL(-.3,7.,.1,%REF(TITLE),90.,14)
      CALL NUMBER(-.3,8.6,.2,FLOAT(IDREC(16)),90.,1)
      CALL PLOT(0.,0.,3)
      CALL PLOTT(FTIM,FDATA,3,XST,SCALE,5000,IREC,c1,c2)
      IFIRST=0
C
C     ADD-UP NUMBER OF DATA POINTS EXCEEDING
C     AMPLITUDE X AND DIVIDE BY TOTAL DATA
C     POINTS IN RECORD. USE LOGARITHMIC
C     PLOTTING INTERVAL.
C
      NPT=100
      A = 5000.
      B = 5000.
      DO 401 ICH=1,2
      C=AVEKK
      IF(ICH.EQ.2) C=AVELL
      DO 351 K=1,npt
      FX=K*C
      X(K)=FX
      COUNT = 0.
      DO 501 L=1,5000
      IF(FDATA(ICH,L).GT.FX) COUNT = COUNT+1
501   CONTINUE
      PERCENT(ICH,K) =
     1 (PERCENT(ICH,K)*A+COUNT)/B
      WRITE(6,1) ICH,K,X(K),COUNT,PERCENT(ICH,K)
1     FORMAT(' CHANNEL,K,X,COUNT,PERCENT   ',2I5,3F15.4)
351   CONTINUE
401   CONTINUE
      GO TO 1005
900   WRITE(6,2)
2     FORMAT(' ERROR IN INITIALIZING TAPE')
      GO TO 1000
901   WRITE(6,3)
3     FORMAT(' END OF TAPE ASSUMED')
C
C     PLOT THE CUMULATIVE APD FOR THE ENTIRE TAPE
C
```

```
1005   CH1=C1/80
       CH2=C2/80
       XSCALE=3.333
       YSCALE=1.333
       CALL PLOT(11.0,0.,-3)
       CALL PLOTT(X,PERCENT,1,XSCALE,YSCALE,npt,IREC,CH1,CH2)
       GO TO 1007
1004   WRITE(6,1006) IREC
1006   FORMAT(' END OF DISK OR TAPE FILE DETECTED
     1 AFTER RECORD NUMBER    ',I5)
C
C      NOW PLOT TAPE ID PARAMETERS ON PLOT HEADER
C
1007   IDREC(29)=IREC
       IDREC(28) = IPAR
       IDREC(27) = 1
       CALL PLOT(9.5,0.,-3)
       CALL HEADER(NID)
1000   CALL PLOTND
       CLOSE(UNIT=1)
       STOP
       END
```

```
      PROGRAM  TPD
C
C     THIS PROGRAM COMPUTES THE TIME PROBABILITY
C     DISTRIBUTION FOR A USER-SELECTED SAMPLE OF DATA
C
C     WRITTEN BY DR  STEN ODENWALD
C
C
      COMMON/HEADER/ IDREC(30), IST(4), STSC, SPSC
      COMMON/DATA/ IDATA(2, 10000), NCH
      COMMON/AUTO/ TPD(2, 3, 5000)
      COMMON/TIME/ IH, IM, SEC, ATIM(5000)
      CHARACTER*30 FILENAM
      CHARACTER*14 TITLE
      CHARACTER BUFFER*32768
      BYTE JDATA(32768), TEST(100)
      EQUIVALENCE (JDATA, BUFFER)
      DIMENSION FMAX(2, 2000),  sum(5000), REF1(100), REF2(100)
      DIMENSION ftpd(2, 3), X(5000), PERCENT(2, 5000), SIGMA(2, 2000)
      DIMENSION AVE(2, 2000), FTIM(5000), FDATA(2, 5000), TIM(2000)
      LOGICAL ERRFLG
      TYPE*, 'TYPE INCREMENT'
      READ*, INNX
      NX=1000/INNX
      DO 8870 I=1, NX
      X(I)=INNX*(I-1)
8870  CONTINUE
C
C     NUMBER OF STEPS IN AUTOCORRELATION FUNCTION
C
C     NX=32
C     NX=10
C
C     OPEN THE TAPE FILE ON THE SCRATCH DISC CONTAINING
C     THE DATA FROM THE GWEN OBSERVING RUN
C
C     TYPE*, 'INPUT TAPE FILE NAME'
C     READ(5, 333) FILENAM
C     FILENAM='SIA1: [ODENWALD]B. DAT'
333   FORMAT(5X, A30)
      OPEN(UNIT=1, CARRIAGECONTROL='LIST',
     1STATUS='UNKNOWN', RECORDSIZE=20040)
C
C     INITIALIZE PLOT UTILITY
      CALL PLOTST(5, 'IN', 0)
      IFIRST=1
C
C     IDATA CONTAINS THE INTEGER VALUES FOR UP TO
C     10, 000 DATA SAMPLES FOR TWO CHANNELS EACH
C     HAVING N1 AND N2 SAMPLES RESPECTIVELY.
C
C     ITPD IS THE VECTOR CONTAINING THE THREE
C     THRESHOLD SENSITIVITY LEVELS FOR THE TPD
C
C
C     PROGRAM BEGINS
C
C     DEFINE NUMBER OF WORDS IN DATA RECORD
C                               ID RECORD
      NDA = 10000
      NID = 20
```

```
      NTOT=NDA+NID
      NBY = 2*NTOT
C
C     NUMBER OF TAPE RECORDS
C
      MREC = 1120
      NSKIP = 0
      DO 88 I=1,30
      IDREC(I)=0
88    CONTINUE
      DO 23 I=1,2
      DO 24 J=1,1000
      PERCENT(I,J)=0.
24    CONTINUE
23    CONTINUE
      type*,'record number
      READ*,Irec
      NSKIP=IREC-1
      MREC=1
      IDREC(30)=1
C
C     READ TAPE RECORD OF LENGTH NBY BYTES
C
      ISTT=1
      IPAR = 0
      NCH = 2
      IPLOT=1
      IF(NSKIP.EQ.0) GO TO 202
      DO 201 II=1,NSKIP
      READ(1,5) BUFFER
5     FORMAT(A)
201   CONTINUE
202   READ(1,5,END=1004) BUFFER
C     WRITE(6,888) (JDATA(I),I=1,10)
C888  FORMAT(10I5)
C
887   CALL DECODE(JDATA,NBY,IREC,ISTT)
c
C     see if the gain setting has changed
c
      GAIN=1.
      JGAIN=IDREC(16)
      IF(JGAIN.EQ.0) JGAIN=1
      IF(JGAIN.EQ.2) GAIN=.0631
      IF(JGAIN.EQ.4) GAIN = .00668
      IF(JGAIN.EQ.8) GAIN = .000708
C
      DELT=1000./6200.
      SUM1=0.
      SUM2=0.
      KK=1
      DO 32 I=1,5000
      FTIM(I)=I*DELT
      fdata(1,i)=(1.0*idata(1,i)/16.)**2.
      fdata(2,i)=(1.0*IDATA(2,I)/16.)**2.
      SUM1=SUM1+FDATA(1,I)
      SUM2=SUM2+FDATA(2,I)
32    CONTINUE
      AVEKK=SUM1/5000.
      AVELL=SUM2/5000.
      XST=10./(5000.*DELT)
```

```
      YS1= 1/AVEKK
      YS0 =  1/AVELL
c
c     determine the y axis limit IN UNITS OF
c     10(-15) WATTS/METER SQUARE/HERTZ
c
      SCALE=YS1
      IF(FDATA(1,10) LT FDATA(2,10)) SCALE=YS0
      AAA=8 *8.62e-4/(GAIN*SCALE)
      BBB=8 *8.62e-4*10**(30./20.)/(GAIN*SCALE)
      c1 = aaa
      c2 = bbb
c     if(fdata(2,1) gt fdata(1,1)) c1 = bbb
c     if(fdata(2,1) gt fdata(1,1)) c2 = aaa
c     TYPE*,'LBL1,LBL2',C1,C2
      IF(IDREC(4).NE.6) GO TO 1113
      IF(IDREC(5).LT.15) GO TO 1113
c
c     IF BOTH ARE TRUE, THE GAINS ARE THE SAME FOR
c     EACH PLOT
c
      IF(C1.GT.C2) C2=C1
      TYPE*,C1,C2
      IF(C1.LT.C2) C1=C2
      TYPE*,C1,C2
1113  IF(IFIRST.EQ.1)CALL PLOT(.5,2.,-3)
      TITLE='ATTENUATION = '
      IF(IFIRST.EQ.0) CALL PLOT(11.,0.,-3)
      CALL SYMBOL(-.3,7.,.1,%REF(TITLE),90.,14)
      CALL NUMBER(-.3,8.6,.2,FLOAT(JGAIN),90.,1)
      CALL PLOT(0.,0.,3)
      CALL PLOTT(FTIM,FDATA,3,XST,SCALE,5000,IREC,c1,c2)
      IFIRST=0
      TYPE*,'TYPICAL SIGNAL VALUES '
      TYPE*,fdata(1,5),fdata(2,5)
      TYPE*,'TYPE TWO THRESHOLDS TO USE'
      READ*,FTPD(1,2),FTPD(1,3)
      READ*,FTPD(2,2),FTPD(2,3)
      FTPD(1,1)=1.0
      FTPD(2,1)=1.0
C
C     PLOT THE THRESHOLDS ON THE RECORD PLOT
C
      DO 350 I=1,2
      XO=4.*I
      DO 351 J=1,3
      XX=XO-SCALE*FTPD(I,J)
      CALL PLOT(XX,0.,3)
      CALL PLOT(XX,10.,2)
      CALL NUMBER(XX,10.3,.1,FLOAT(J),90.,1)
351   CONTINUE
350   CONTINUE
      TPINC=1.
c
c     compute the differential tpd
c     THAT IS, THE NUMBER OF TIMES THAT THE PULSES
C     ARE SPACED BY I MILLISECONDS
C
      DO 700 L=1,3
      DO 400 J=1,2
      DO 600 I=1,NX
```

```
      TP = 0.
      IMAX = 5000-X(I)
      DO 550 K=1,IMAX
      INDX=X(I)+K
      IF(fdata(J,K) LT FTPD(J,L)) GO TO 550
      IF(fdata(J,INDX).LT.FTPD(J,L)) GO TO 550
      TP=TP+1
550   CONTINUE
      IF(I.EQ.1) TPO=TP
      TPD(J,L,I)= TP/TPO
C     TYPE*,'TP,TPO,TPD(J,L,I)',TP,TPO,TPD(J,L,I)
      if(tpd(j,l,i).lt..00001) tpd(j,l,i)=.00001
C     WRITE(6,93) J,L,I,X(I),FTPD(J,L),TPD(J,L,I)
C93   FORMAT(' J,L,I,X,TRSH,TPD  ',3I5,3F15.5)
600   CONTINUE
C
C     now sum the differential tpd to find the integral
C     IE THE NUMBER OF TIMES THAT THE PULSE SPACINGS
C     ARE GREATER THAN I
C
      NXX=NX-1
C     TYPE*,'CHANNEL,THRESHOLD   ',J,L
      do 601 i=1,nxX
      sum(i)=0.0
      do 602 ii=i+1,nx
      IF(TPD(J,L,I).LT..00001) TPD(J,L,I)=.00001
      sum(i)=sum(i)+tpd(j,l,ii)
C     TYPE*,'I,SUM',I,SUM(I)
      IF(I.NE.1) GO TO 602
C
C     COMPUTE NORMALIZATIONS TO INTEGRAL
C     OVER ALL TIME INTERVALS
C
      IF(J.EQ.1) REF1(L)=SUM(I)
      IF(J.EQ.2) REF2(L)=SUM(I)
602   continue
603   IF(J.EQ.1)
     1 TPDI= SUM(I)/REF1(L)
      IF(J.EQ.2)
     1 TPDI= SUM(I)/REF2(L)
C     TYPE*,'I,SUM(I),TPDI', I, SUM(I),TPDI
      IF(ABS(TPDI-1.).LT..001) TPDI=.977240
      IF(TPDI.GT..977240) TPDI=.977240
      IF(TPDI.LT..0000001) TPDI=1.0E-10
      TPD(J,L,I)=1.-ALOG10(ALOG10(1./TPDI))
C     TYPE*,J,L,I,SUM(I),TPDI,TPD(J,L,I)
C     IF(J.EQ.1) WRITE(6,3334) I,J,L,SUM(I),REF1(L),TPD1,TPDI
C     IF(J.EQ.2) WRITE(6,3334) I,J,L,SUM(I),REF2(L),TPD1,TPDI
3334  FORMAT(' I,J,L,SUM,REF,LOGSM,TPD ',3I5,4F15.5)
601   continue
400   CONTINUE
700   CONTINUE
      GO TO 1005
900   WRITE(6,2)
2     FORMAT(' ERROR IN INITIALIZING TAPE')
      GO TO 1000
901   WRITE(6,3)
3     FORMAT(' END OF TAPE ASSUMED')
C
C     PLOT THE TPD
C
```

```
1005   CH1=(10 /5000. )*1000. * 8057
       CH2=C2/80
       XSCALE=1. 333
       YSCALE=1. 333
       CALL PLOT(11. 0,0 , -3)
       WRITE(6,3333), (((TPD(I, J, K), I=1, 2), J=1, 3), K=1, NXX)
3333   FORMAT(' ', 6F10. 5)
       CALL PLOTT(X, PERCENT, 2, XSCALE, YSCALE, NXX, IREC, CH1, CH2)
       GO TO 1007
1004   WRITE(6, 1006) IREC
1006   FORMAT(' END OF DISK OR TAPE FILE DETECTED
     1 AFTER RECORD NUMBER    ', I5)
C
C      NOW PLOT TAPE ID PARAMETERS ON PLOT HEADER
C
1007   IDREC(29)=IREC
       IDREC(28) = IPAR
       IDREC(27) = 1
       CALL PLOT(9. 5, 0. , -3)
       CALL HEADER(NID)
1000   CALL PLOTND
       CLOSE(UNIT=1)
       STOP
       END
```

```
        .TITLE          BYSWAP - SWAP BYTES OF WORDS AND MASK LOWER 10 BITS
;
;
;   SUBROUTINE TO SWAP BYTES IN A 16 BIT WORD
;
;   INPUT:
;
;       4(AP) - ARRAY ADDRESS OF 16 BIT ELEMENTS TO BE BYTE
;               SWAPPED AND MASKED
;
;       @8(AP) - NUMBER OF 16 BIT ELEMENTS IN THE INPUT ARRAY
;                TO PROCESS
;
;   OUTPUT:
;
;       THE RESULTANT ARRAY OF 16 BIT SWAPPED ELEMENTS
;       OVERLAYS THE INPUT ARRAY
;
;   THIS SUBROUTINE IS FORTRAN CALLABLE, AS IN:
;
;               CALL BYSWAP(IARRAY,NUMBER)
;
;       WHERE IARRAY IS THE I*2 ARRAY OF DATA TO BE PROCESSED AND
;       NUMBER IS THE I*2 NUMBER OF 16 BIT ELEMENTS IN IARRAY.
;
;
        .PSECT          CODE,RD,NOWRT,EXE,LONG
        .ENTRY          BYSWAP,^M<IV,R2>
        MOVL            4(AP),R1                ;PICK UP ARRAY ADDRESS
        CLRL            R2
        MOVW            @8(AP),R2               ;R2 = NUMBER OF ELEMENTS TO PROCESS
        BLEQ            RETURN                  ;DO NOTHING IF INVALID COUNT
LOOP:   EXTZV           #8,#8,(R1),R0           ;PLACE 8 MSBits of source into LSbits of R0
        INSV            (R1),#8,#8,R0           ;and 8 LSBits of source into MSbits  of R0
        MOVW            R0,(R1)+                ;move result to overwrite input
        SOBGTR          R2,LOOP                 ;do again for each element
RETURN:
        RET                                     ;DONE, RETURN TO CALLER
        .END
```

END

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